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SWATH DYNAMIC SIMULATION MODEL.(U)
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A five degree of freedom (constant pitch) simulation model for a Small Waterplane Area Twin Hull (SWATH) ship has been developed. Complete descriptions of the mathematical models employed and a description of the corresponding digital simulation program are presented in this report. Performance predictions based on the mathematical model are also included. The mathematical models are based primarily on experimental model test data measured at the rotating arm facility at the David W. Taylor Naval Ship

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ABSTRACT

A five degree of freedom (constant pitch) simulation model for a Small Waterplane Area Twin Hull (SWATH) ship has been developed. Complete descriptions of the mathematical models employed and a description of the corresponding digital simulation program are presented in this report. Performance predictions based on the mathematical model are also included. The mathematical models are based primarily on experimental model test data measured at the rotating arm facility at the David W. Taylor Naval Ship Research and Development Center (DTNSRDC). The performance predictions generated in this study are appropriate for carrying out rudder configuration design evaluations. The results indicate that the spade rudder configuration is adequate for meeting turn diameter specifications.

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INTRODUCTION

The Navy is currently carrying out preliminary design and feasibility studies on various Small Waterplane Area Twin Hull (SWATH) ship configurations in the 2000 - 20,000 ton weight range. These ships have desirable performance properties due to their design. The SWATH ship basic configuration consists of two submerged hulls attached to two vertical struts. Propulsion is provided by propellers located at the end of the hulls. Since the waterplane is small, surface waves have a smaller effect on SWATH ship motion than on conventional craft which have larger waterplane areas. Also, SWATH ships can turn in a fairly small circle at low speed by applying a differential thrust. A sketch of the basic SWATH configuration is illustrated in Figure 1.

In order to carry out evaluation studies, the necessary tools must be developed. One such tool is a time domain simulation model suitable for predicting ship behavior during various maneuvers. The simulation model must be sufficiently flexible so that different SWATH configurations can be easily evaluated and compared. An appropriate simulation tool has been developed during the study reported here.

The general approach used in developing the SWATH simulation model involves the development of mathematical models based on experimental force and moment data. The experimental data is first processed to develop a sufficiently dense data base by interpolating and/or extrapolating for missing grid points. Also, symmetry properties are employed to generate a complete data base required to characterize the ship over all orientations and speeds. The force and moment values for a given ship state are obtained via multidimensional interpolation of the data base. Theoretical expressions are used whenever experimental model data is lacking.

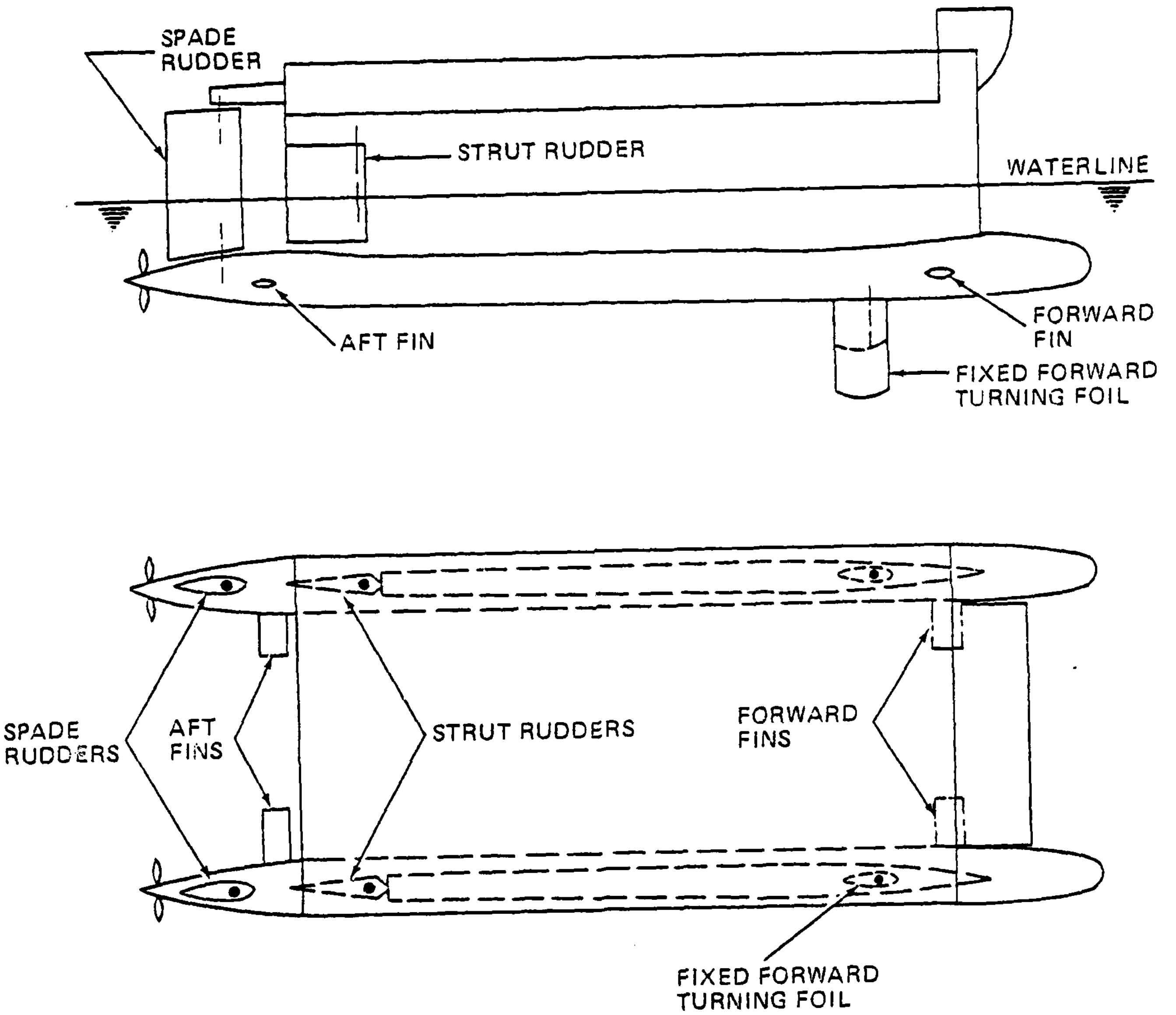

FIGURE 1 SCHEMATIC OF SWATH 6A CONFIGURATION

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The resulting force and moment models are used in the differential equations that describe the ship motion. These equations are solved numerically using standard integration procedures.

Various sets of experimental data are used in the present effort. These data characterize the hull, rudder, fin, and propulsion subsystems. These subsystems are modeled separately. However, some interference effects are taken into account. For example, the interference of a hull on its propeller is accounted for by a wake reduction factor based on experimental data. Other interference effects are assumed negligible. These assumptions are validated via an analysis of the experimental data in most cases.

The mathematical model development is presented in the next section. Subsequent sections present results and digital computer program documentation. Actual computer output and card images of various test runs are presented in the appendices.

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MATHEMATICAL MODEL DEVELOPMENT

BASIC EQUATIONS OF MOTION

The equations governing the motion of the SWATH are extensions of Newton's second law, F = Ma, to the six degrees of freedom possible for ship motion. The SWATH simulation model is based on the standard equations of motion for a submarine outlined in NSRDC Report No. 2510. Minor changes have been made in converting the submarine equations to a set of equations appropriate for a surface ship. The predominate coordinate system used in the simulation model is a body fixed system as defined in reference #2510. All forces and moments are defined in terms of the body system. Unless otherwise specified all parameters are given in the MKS system of units.

The equations of motion presented in NSRDC Report No. 2510 can be written in the generalized form,

$$\dot{\vec{S}} = A^{-1} \vec{F}$$

where $\dot{\vec{S}}$ is the state vector, A is a generalized mass/inertia matrix and $\vec{F}$ is a generalized force vector.

The generalized mass/inertia matrix appropriate for SWATH is presented in Table 1. All symbols used in Table 1 and in subsequent sections of this report are defined in the notation section. The generalized force vector, $\vec{F}$, contains kinematic terms plus contributions from the fin, hull, rudder, aerodynamic, buoyancy, propeller, and rate dependent forces and moments. The components of the generalized force vector are defined in Table 2.

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$$
\begin{matrix}
\bar{M} - X_{\dot{u}} & 0 & 0 & 0 & \bar{M} \cdot Z_g & -\bar{M} \cdot Y_g \\
0 & \bar{M} - Y_{\dot{v}} & 0 & -\bar{M} \cdot Z_g - Y_{\dot{p}} & 0 & \bar{M} \cdot X_g - Y_{\dot{r}} \\
0 & 0 & \bar{M} - Z_{\dot{w}} & \bar{M} \cdot Y_g & -\bar{M} \cdot X_g - Z_{\dot{q}} & 0 \\
0 & -\bar{M} \cdot Z_g - K_{\dot{v}} & \bar{M} \cdot Y_g & I_{xx} - K_{\dot{p}} & -I_{xy} & -I_{xz} - K_{\dot{r}} \\
\bar{M} \cdot Z_g & 0 & -\bar{M} \cdot X_g - M_{\dot{w}} & -I_{xy} & I_{yy} - M_{\dot{q}} & -I_{yz} \\
-\bar{M} \cdot Y_g & \bar{M} \cdot X_g - N_{\dot{v}} & 0 & -I_{xz} - N_{\dot{p}} & -I_{yz} & I_{zz} - N_{\dot{r}}
\end{matrix}
$$

Table 1 - GENERALIZED MASS/INERTIA MATRIX

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$$\begin{bmatrix} F_1 \\ F_2 \\ F_3 \\ F_4 \\ F_5 \\ F_6 \end{bmatrix} = \begin{bmatrix} X_{fin} + X_{rud} + X_{hull} + X_{air} + X_{buoy} + X_{prop} + X_{add} + \\ (v \cdot r - w \cdot q)\overline{M} + \left|(q^2 + r^2)x_g - pqy_g - prz_g\right| \\ Y_{fin} + Y_{rud} + Y_{hull} + Y_{air} + Y_{buoy} + Y_{prop} + X_{add} + \\ (wp - ur)\overline{M} + \left|(r^2 + p^2)y_g - qrz_g - qpx_g\right|\overline{M} \\ Z_{fin} + Z_{rud} + Z_{hull} + Z_{air} + Z_{buoy} + Z_{prop} + Z_{add} + \\ (uq - vp)\overline{M} + \left|(p^2 + q^2)z_g - rpx_g - rqy_g\right|\overline{M} \\ K_{fin} + K_{rud} + K_{hull} + K_{air} + K_{buoy} + K_{prop} + K_{add} + \\ (I_{yy} - I_{zz})qr + I_{xz}pq + (q^2 - r^2)I_{yz} - I_{xy}pr + \left|(ur - wp)\ z_g + (u_g - vp)y\right|\overline{M} \\ M_{fin} + M_{rud} + M_{hull} + M_{air} + M_{buoy} + M_{prop} + M_{add} + \\ (I_{zz} - I_{xx})rp + I_{xy}qr + (r^2 - p^2)I_{xz} - I_{yz}qp + \left|(vp - uq)x_g + (vr - wq)z_g\right|\overline{M} \\ N_{fin} + N_{rud} + N_{hull} + N_{air} + N_{buoy} + N_{prop} + N_{add} + \\ (I_{xx} - I_{yy})pq + I_{yz}rp + (p^2 - q^2)I_{xy} - I_{xz}rq + \left|(wq - vr)y_g + (wp - ur)x_g\right|\overline{M} \end{bmatrix}$$

Table 2 - GENERALIZED FORCE VECTOR

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The time rate of change of the roll, pitch, and yaw angles are obtained by solving the kinematic equations presented in Report No. 2510 for $\dot{\phi}$, $\dot{\theta}$, and $\dot{\psi}$. The results are,

$$\dot{\phi} = (q \sin\theta \sin\phi + r \sin\theta \cos\phi + p \cos\theta)/\cos\theta, \tag{2}$$

$$\dot{\theta} = q \cos\phi - r \sin\phi, \tag{3}$$

$$\dot{\psi} = (q \sin\phi + r \cos\phi)/\cos\theta. \tag{4}$$

Velocity components in the fixed or Earth coordinate system are obtained by transforming the body x, y, and z velocity components to the fixed system:

$$\begin{bmatrix} \dot{X}_E \\ \dot{Y}_E \\ \dot{Z}_E \end{bmatrix} = \overleftrightarrow{T} \begin{bmatrix} U \\ V \\ W \end{bmatrix} \tag{5}$$

The transformation matrix $\overleftrightarrow{T}$ is given in Table 3.

The above equations of motion are suitable for a full six degree of freedom simulation model. The SWATH ship considered in this report has four fins that can be used to provide a pitch moment such that the pitch angle remains constant, i.e., $\dot{\theta} = 0.0$.. Rather than solve the extremely complicated problem of determining a fin angle of attack that would result in a value of $\dot{q}$ that would in turn result in a constant pitch, the kinematic equations can be used to obtain a differential equation for $\dot{q}$ such that the pitch remains constant.* When $\dot{\theta} = 0.0$, Equation (3) reduces to

---

* $\dot{\theta} = 0.0$ does not imply $q = 0.0$ unless $\phi = 0.0$ or $r = 0.0$.

$$\overleftrightarrow{T} = \begin{pmatrix} \cos\theta \cos\psi & -\cos\phi \sin\psi + \sin\phi \sin\theta \cos\psi & \sin\phi \sin\psi + \sin\theta \cos\phi \cos\psi \\ \cos\theta \sin\psi & \cos\phi \, \mathrm{co}\psi + \sin\phi \sin\theta \sin\psi & -\sin\phi \cos\psi + \sin\theta \cos\phi \sin\psi \\ -\sin\theta & \sin\phi \cos\theta & \cos\theta \cos\phi \end{pmatrix}$$

TABLE 3 BODY TO FIXED COORDINATE SYSTEM TRANSMISSION MATRIX

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$$q \cos\phi - r \sin\phi = 0.0. \qquad (6)$$

A differential equation for q is obtained by taking the derivative of the above equation:

$$\dot{q} \cos\phi - \dot{r} \sin\phi = \dot{\phi}\ (q \sin\phi + r \cos\phi). \qquad (7)$$

$\dot{\phi}$ can be eliminated in the above equation by using Equation (2). The constant pitch simulation model employs the above equation for $\dot{q}$ rather than the $\dot{q}$ equation given in Report No. 2510. Conceptually, the above approach is equivalent to including a fin pitch moment in the pitch equation such that $\dot{\theta} = 0.0$. In fact, if a strongly restoring pitch moment of the form

$$M = C\theta$$

is included in the differential equation for q in six degrees of freedom, the pitch moment remains at a value of zero degrees. Such a test was conducted in order to verify the five degree of freedom equations.

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HULL HYDRODYNAMIC FORCE AND MOMENT MODEL

The mathematical models used to represent hull forces and moments are based on experimental model data provided by DTNSRDC. The data supplied was obtained from experiments conducted on a 1/22.5 size scale model at the rotating arm facility located at DTNSRDC. Six different model configurations, as described in Table 4 , were considered. The results of these experiments were supplied in the form of parametric curves for non-dimensional values of Y, K, and N versus non-dimensional turn rate for various drift angles. Measurements were not made for isolated grid points. These missing values were obtained by interpolation or extrapolation based on an inspection of various data trends. The final data bases used to characterize the hydrodynamic hull forces and moments are presented in Tables A1 - A4. A four variable table look-up or interpolation procedure is used in the digital simulation model to obtain values of Y, K, and N at given values of the speed, roll angle, drift angle, and non-dimensional yaw rate from the dimensional form of the data base. Interpolations were initially performed on the non-dimensional form of the data base. However, due to the fine sampling in speed (5 knot spacings) linear interpolation of the dimensional form of the data is sufficiently accurate and much more efficient. A comparison of both results is illustrated in Figures 2-4. The experimental data plotted in these figures are hand faired using French curves. The very close agreement between the interpolated values and the smooth curves indicate the high degree of accuracy possible by use of an interpolation procedure. Note that the data bases contain rudder contributions at zero rudder angle. Also, it is assumed that the force coefficients can be superimposed due to the strong linear nature of the forces and moments.

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Case	Rudder Configuration	Draft	Speed* knots	Roll deg	Drift deg	Yaw+ Rate
A	Strut rudders and fins at zero deflection	Design	5 - 28	0 - 4	-4 to 4	0.09 - 0.305
B	Same as above	Deep	5 - 28	0 - 4	-4 to 4	0.09 - 0.305
C	Strut rudders, spade rudder, fins at zero deflection	Design	5 - 28	0 - 4	-4 to 4	0.09 - 0.305
D	Same as above	Deep	5 - 28	0 - 4	-4 to 4	0.09 - 0.305
E	Strut rudders and fins at zero deflection. Fixed forward foil extended	Design	5 - 28	0 - 4	-4 to 4	0.09 - 0.305
F	Same as above	Deep	5 - 28	0 - 4	-4 to 4	0.09 - 0.305

*Full Scale

+Non-dimensional: $r' = rL/u$

TABLE 4 DESCRIPTION OF TEST CASES A - F

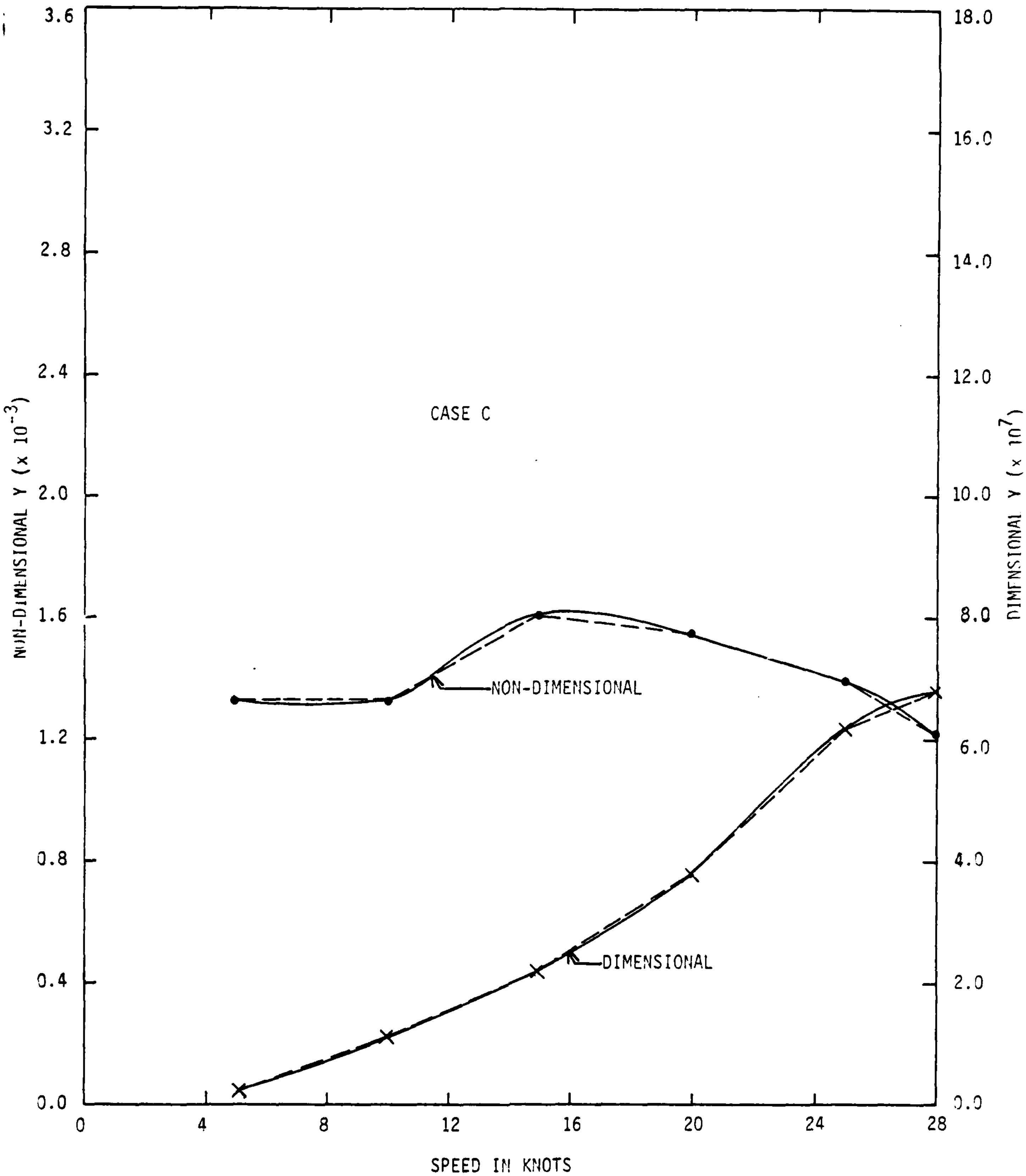

FIGURE 2 Y VS SPEED FOR ROLL = 6°, DRIFT = 4°, r' = 0.3

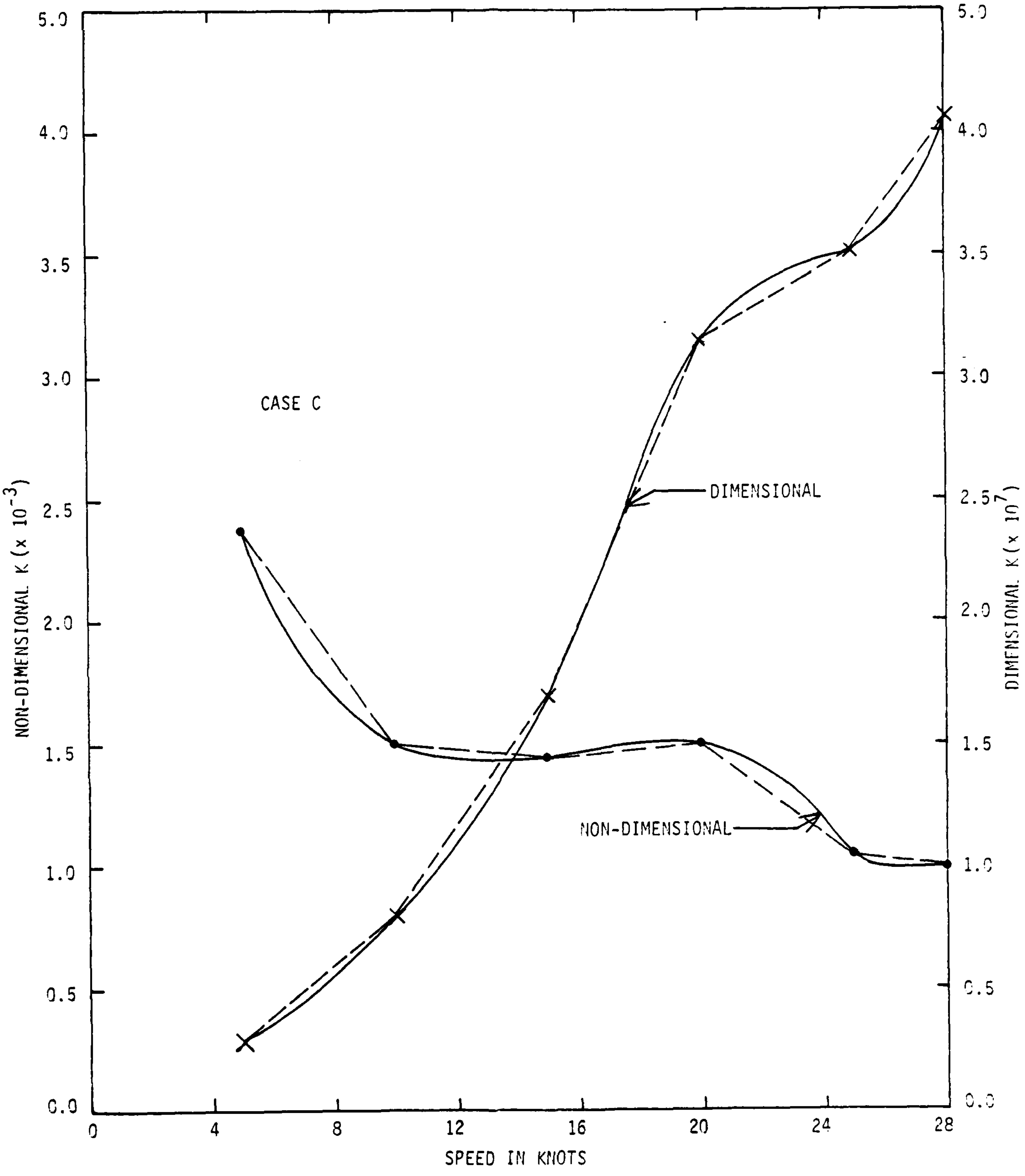

FIGURE 3 K VS SPEED FOR ROLL = -6°, DRIFT = -4°, $r' = -0.3$

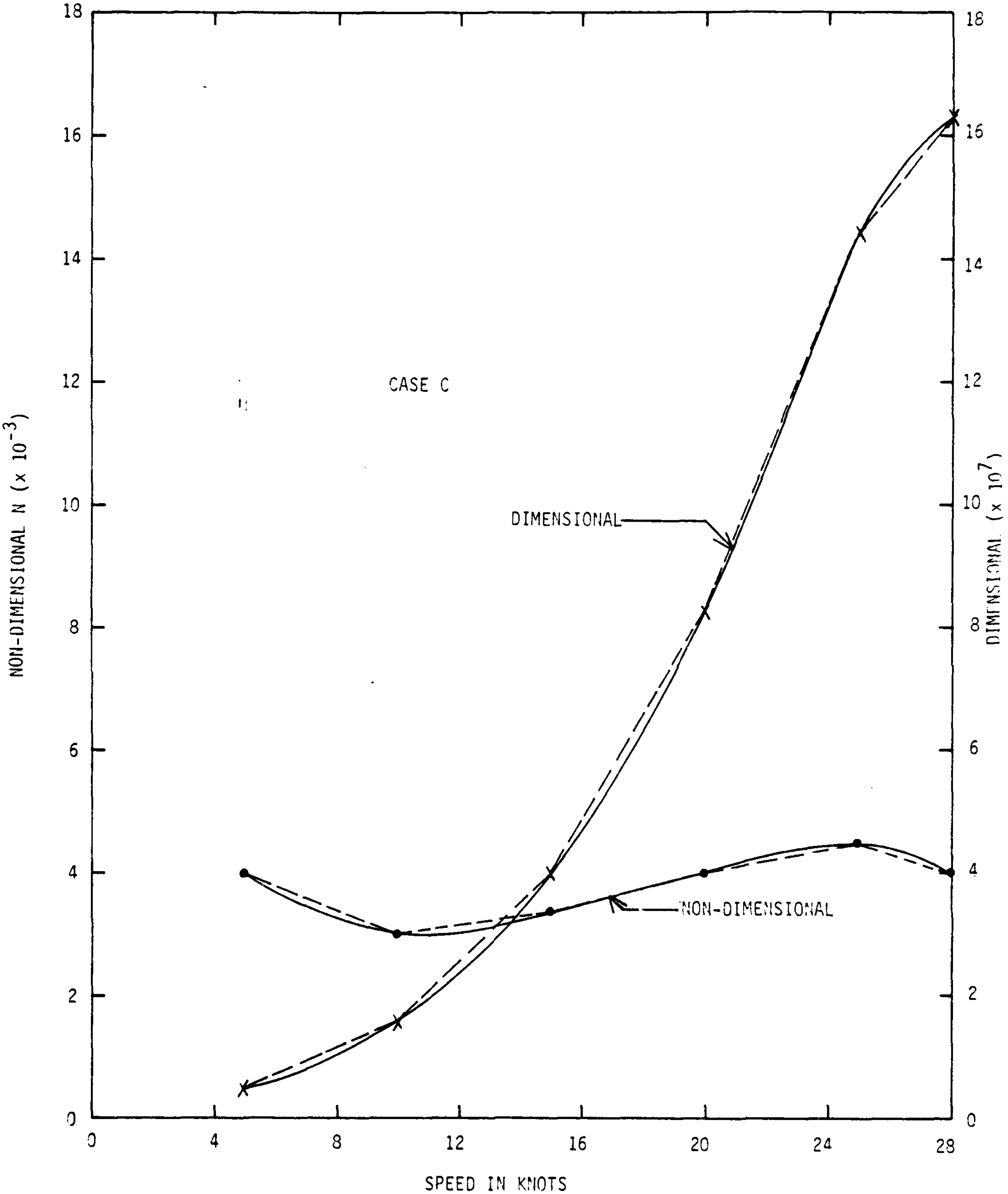

FIGURE 4 N VS SPEED FOR ROLL = DRIFT = 0^{o}, r' = -0.3

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The range of variables covered in the final data base used in the mathematical model proved adequate for all simulated maneuvers except for turns carried out by application of a differential thrust at 5 knots. For these cases, the non-dimensional turn rate ($r' \lambda r/u$, $u \to 0$) can be as large as 1.5 and drift angles as large as 10.0^{o}. However, a linear extrapolation of the available data should produce reasonable results since all low speed parametric curves examined show strong linearity.

The drag alone the body x direction is calculated from EHP curves provided by DTNSRDC. For a given value of the EHP, the drag is obtained from the formula,

$$\text{Drag} = (\text{EHP} \cdot 326)/U,$$

where U is the speed in knots. This mathematical is strictly valid for straight ahead flight at zero trim. Effects of ship motion can be easily taken into account when more extensive EHP data becomes available. The effect of changes in drag due to changes in ship immersion is taken into account by computing the percent changes in frontal and wetted areas from ship geometrical factors. The resulting drag formula is given by,

$$R' = R(1.0 + 0.08(Z_o + Z_E)),$$

where R is the nominal resistance that would be obtained for $Z_E = 0.0$, Z_o is a reference heave in meters, and Z_E is the heave, which is assumed positive downward. Although the above formula is approximate, it should be sufficiently accurate for purposes of the present study since changes in drag will be small due to the small waterplane area, and due to the small changes of immersion encountered.

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A vertical force model was developed based on data provided by DTNSRDC. Due to the wide scatter in the data, the only variable having a discernable effect on z appears to be the speed. An analysis of the data provided leads to the following model:

$$Z = (1.53 + 0.125U)\rho L^2 U^2/2000.$$

The magnitude of the above force results in only minor changes in heave. For example, at a speed of 25 knots, the vertical force will result in a change in heave of approximately 0.25 meters.

A hull pitch moment is estimated from the drag force times an appropriate moment arm. The moment arm is chosen such that the resulting pitch moment is zero during straight ahead flight at zero degree trim.

RUDDER FORCE AND MOMENT MODEL

Experimental data for the rudder X, Y, K and N forces were provided by DTNSRDC in a form similar to the hull force data. Only two parameters were varied, the rudder angle of attack and the speed. Since the hull data contained the effect of zero rudder angle, the rudder force described in this section represents the increment in force due to non-zero angle of attack on the rudder. From geometric considerations, the angle of attack on the rudder used in the rudder force model equals the rudder deflection angle. If, instead, the rudder forces had not been included in the hull, the appropriate rudder angle would be the actual inflow angle on the rudder, dependent not only on the deflection angle but also on the ship state variables, such as drift angle and yaw rate.

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For various rudder sizes, a combination of theory and empirical considerations yields the equation

$$F = F_o \times \left(\frac{AR'}{AR_o}\right)^{\frac{1}{2}} \times \frac{Area'}{Area_o}$$

where F_o is the force or moment for the design rudder, and AR = aspect ratio. From pure theory, at very high aspect ratios the rudder force is independent of small changes in the aspect ratio and is proportional only to the area change. At very low aspect ratios, the rudder force is proportional to both area change and the percent aspect ratio change. Since the curve is smooth between these two points, for a rudder between these two extremes the rudder force is proportional to $\left(\frac{AR'}{AR_o}\right)^K$ where K lies between zero and one. Based on an examination of experimental data and theoretical considerations, a value of 0.5 is assigned to K. Through the use of this formula, changes in rudder forces due to pitch and immersion changes are included in the rudder force model. The rudder Z force is assumed to be zero, and the pitch moment is calculated as the X force times a moment arm equal to one half the usbmerged rudder draft plus the distance from the coordinate system origin to the waterline. The above formula is approximate. However, only small changes in aspect ratio and areas are considered in this study. Under these conditions, the above formula should be sufficiently accurate.

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Data was also supplied for the fixed forward rudder (Case E and F). By subtracting the Case A (no fixed forward rudder) forces from the Case E forces, one obtains a data base for the fixed forward rudder as a function of the three parameters: speed, drift angle and yaw rate. The drag data for the fixed rudder are quite scattered. Because of this, the theoretical approximations relating drag to lift is used: drag = lift/7. Since the additional drag of the rudder is but a small fraction of the total drag, this approximation is adequate.

A three dimensional interpolation procedure is used to obtain the appropriate non-dimensional fixed rudder forces. It should be noted that only one fixed rudder will be used at a time, the starboard one for starboard turns and vice versa. During the transition time of zero extension to full extension, the forces are assumed to be in direct proportion to the ratio of extended length/full length.

FIN FORCE AND MOMENT MODEL

The SWATH configurations considered in this study have four horizontal fins located on the inside of the hulls, two forward and two aft. The angle of attack of these fins can be individually changed to control pitch, induce roll, and control depth. The mathematical model used to characterize the fin lift is given by,

$$\text{Lift} = (1/2)\rho A U_f^2 \frac{\partial C_L}{\partial \alpha} \alpha$$

where

A = fin area or chord X span

U_f = local inflow velocity

$\frac{\partial C_L}{\partial \alpha}$ = lift coefficient slope.

α = fin angle of attack.

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The value of the lift coefficient slope is obtained from data supplied by DTNSRDC. The values for the slope remain constant for fin angles of attack up to 15^{0}, after which stall occurs resulting in a rapid decrease in lift. For fin angles of attack less than 15^{0}, there is good correlation between the measured value of 1.19 and the theoretical value of 1.3. Since the slope of the lift coefficient agrees quite well with the theoretical prediction, it is assumed that the actual lift/drag ratio can be adequately approximated by the theoretical prediction for similar fins. The increment in drag due to non-zero fin angle of attack is obtained directly from the lift/drag ratio and the lift. The fin drag at zero angle of attack is contained in the hull force data base.

The fin angle of attack is dependent on the fin deflection angle and the ship velocities. The local velocities are given by

$$U_f = U - r.Y_f + q \cdot Z_f,$$

$$W_f = W - p \cdot Z_f + r \cdot X_f,$$

where X_f, Y_f, and Z_f are the coordinate location of the fin. It is assumed that the fluid flow parallel to the fin span has a negligible effect on the fin lift and drag. Since the fin lift and drag are perpendicular and parallel to the stream flow, these values are transformed to the body coordinate system. The force along the body y axis is assumed to be zero. The roll, pitch, and yaw moments are obtained from the transformed forces by multiplying by appropriate moment arms. The center of pressure is assumed to be at the one quarter chord and one half span.

Note that the fin model is valid only up to angles of attack of approximately 15^{0}. For larger angles of attack, the model overestimates the

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lift and under estimates the drag since stall effects are neglected. During normal maneuvers, fin angles of attack larger than 15^{o} are rarely required. The results of work being conducted by Dr. C. M. Lee*, DTNSRDC, will be incorporated at a future date prior to carrying out simulation studies using the fins. This effort presents refined estimates appropriate for the fins.

* C. M. Lee and Mr. Martin, "Determination of the Size of Stabilizing Fins for Small Waterplane Area Twin-Hull Ships", DTNSRDC Report 4495, Nov 1974.

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PROPELLER THRUST MODEL

The SWATH configurations considered in this study are driven by two submerged variable pitch propellers. The mathematical model used to represent the thrust is based on experimental data provided by DTNSRDC. These data were obtained for a single SWATH strut/hull/propeller configuration. The value for K_T and K_Q were measured for advance ratios values (J) ranging from -2.5 to 5.0 and for pitch/diameter ratios ranging from -4 to 4. Data were extracted from the curves and are used in a two dimensional interpolation procedure to obtain K_T values. The corresponding thrust is given by the formula,

$$T = K_T \rho n^2 D^4,$$

where

ρ = density of water,

n = rotational speed of the propeller in revolutions per second.

D = propeller diameter.

The thrust is assumed to act along the thrust line used in the experimental testing, which was parallel to the body x axis. In the simulation model, each propeller is treated separately so that differential thrust can be applied.

The advance coefficient is given by

$$J = V_a/(nD),$$

where V_a is the speed of advance of the propeller. The value of V_a is less

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than the ship velocity due to hull interference effects. These hull interference effects are taken into account via a wake fraction. An average value of 0.82 is used in the mathematical model, i. e.,

$$V_a = 0.82 \; U.$$

The propeller forces along the body y and z axes and the roll moment are assumed negligible and not modeled. The pitch and yaw moments are calculated from the propeller thrust times the appropriate moment arms.

The propeller model neglects changes in thrust due to non-zero inflow angle. This effect is small during high speed turns but may become significant for low speed turns that result in large drift angles. The large changes in inflow angle can lead to non-zero values for the propeller forces along the y and z body axes. The effect would be largest for low speed turns (less than 5 knots) carried out by the application of a differential thrust. In these cases the ship transverse velocity can be a significant fraction of the forward speed. Including the effects of changing inflow angles is beyond the scope of the present effort. It is expected that these effects will have a small effect on the predictions presented in this report.

AERODYNAMIC FORCE MODEL

At this time, the forces and moments due to aerodynamic effects have been ignored and set equal to zero. A rough estimate of the magnitude of the aerodynamic forces and moments indicates that a 25 knot wind at 90° would result in a roll angle change of less than 0.25°. Based on this estimate, neglecting the aerodynamic forces and moments is a reasonable approximation.

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BUOYANCY FORCE AND MOMENT MODEL

The buoyancy forces and moments are determined from coefficients Z_Θ, Z_z, M_Θ, and M_z provided by DTNSRDC. The mathematical expressions for the forces and moments are given by,

$$Z_B = Z_\theta \Theta + Z_z Z$$

$$M_B = M_\theta \Theta + M_z Z$$

$$K_B = (\text{Beam}/2)^2 \tan\phi \; Z_z,$$

where Z_z is the combined value for both hulls. The drag, y axis force, and yaw moment due to buoyancy are assumed zero.

RATE DEPENDENT FORCES AND MOMENTS

Various first and second order rate dependent coefficients are contained in the equations of motion. These are of the form X_i and X_{ij} where X represents a force or moment and i and j represent u,v,w,p,q,r. The entire term is the local derivative of X with respect to i(j) so the associated force or moment is equal to $X_{ij} \cdot \bar{i}\bar{j}$, where $\bar{i}$ and $\bar{j}$ represent the velocities of the ship. At the present time, experimental values have not been provided so all terms have been set to zero. Research, that should lead to theoretical estimates of these coefficients is currently underway at DTNSRDC by C. M. Lee, et al.

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SIMULATION PREDICTIONS

The digital simulation system developed during this study has the capability of simulating various maneuvers via simulated pilot actions or commands. The possible pilot actions consist of rudder deflections, propeller RPM changes, propeller pitch changes, fin angle changes, and changes in the position of the forward turning foil. All controlled elements can be independently moved; i. e., the starboard RPM can be set to 0.0 and the port RPM to a non-zero value simultaneously. The occurrence of a pilot action is governed by the value of time and/or state variables. The pilot actions were used to carry out turning maneuvers at high and low speeds, stopping at low speeds, and zigzag type of maneuvers. The results of the turning and stopping simulations are reported in this section.

Several different SWATH ships having various masses and slightly varying length/beam ratios were simulated. Minor modifications in the mathematical models were made to compensate for the dissimilarities between the experimental test model and the actual ship being considered. These modifications were discussed in detail with DTNSRDC personnel prior to generating final results. Results for one set of ship parameters, as listed in Table 5, are presented in this report.

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TABLE 5 -- Design Characteristics of Full Scale SWATH
Used for Sample Predictions

	General Parameters
Linear ratio full scale/model	22.5
Length	73.15m
Strut Length	52.5m
Strut Thickness	2.21m
Transverse Strut Separation	22.86m
Displacement, design draft	2.9×10^6kg
Displacement, deep draft	3.015×10^6kg
Design draft	8.13m
Deep draft	9.27m
Wetted surface, design draft	$2847 m^2$
Wetted surface, deep draft	$3088 m^2$
Longitudinal distance, nose to origin	35.14m
Vertical distance, baseline to origin	10.36m
Forward fins, each:	
Chord	2.61m
Span	2.903m
Aspect ratio	1.11
Longitudinal distance, origin to center of pressure	18.42m
Transverse distance, centerline to center of pressure	7.76m
Vertical distance, origin to center of pressure	8.06m
$\frac{\partial C_L}{\partial \alpha}$, per radian	1.9
Aft fins, each:	
Chord	4.5m
Span	5.0m
Aspect ratio	1.11
Longitudinal distance, origin to center of pressure	26.71m
Transverse distance, centerline to center of pressure	7.76m
Vertical distance, origin to center of pressure	8.06m
$\frac{\partial C_L}{\partial \alpha}$, per radian	1.19

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TABLE 5 -- Design Characteristics of Full Scale SWATH Used for Sample Predictions (cont.)

	General Parameters
Propellers:	
Diameter	4.36m
Nominal Pitch/Diameter ratio	1.0775
Pitch/Diameter range	-0.6 to 1.2
Longitudinal distance, propeller to origin	39.72m
Transverse distance, propeller to centerline	11.43m
Vertical distance, propeller to origin	8.06m
Strut Rudder, each:	
Chord	5.72m
Span	7.32m
Thickness	1.71m
Span, to design waterline	3.0m
Area, to design waterline	21.96m
Longitudinal distance, origin to center of pressure	19.92m
Transverse distance, centerline to center of pressure	11.43m
Vertical distance, origin to center of pressure -- design waterline	3.73m
Spade Rudder, each:	
Chord	5.42m
Span, leading edge	10.82m
Span to design waterline, leading edge	3.85m
Thickness	0.813m
Area, to design waterline	21.9m
longitudinal distance, origin to center of pressure	30.4m
Transverse distance, centerline to center of pressure	11.43m
Vertical distance, origin to center of pressure -- design waterline	4.1m
Fixed forward turning foil:	
Chord	3.49m
Span	6.98m
Aspect ratio	2.0
Area	24.34m^2
Thickness	0.15
Longitudinal distance, origin to center of pressure	18.42m
Transverse distance, centerline to center of pressure	11.43m
Vertical distance, origin to center of pressure	13.85
Fixed angle of attack	5^o

HIGH SPEED TURNS

High speed turn maneuvers are carried out by deflecting the aft rudders from zero degrees to the desired rudder angle at a rate of 5 deg/sec. The simulation is run for a sufficiently long time such that the heading angle changes by 180°.

The desired turn diameter at high speeds was specified to be less than seven ship lengths. A comparison of turn diameters versus rudder angle for strut and spade rudder configurations indicates that the specification can be met by the spade rudder configurations, but not by the strut rudder configurations. A comparison of turning performance at 20 kts for both configurations is presented in Figure 5. The turn diameter specification is met at speeds of 25 kts with the spade rudder configuration, as illustrated in Figure 6.

If turn maneuvers are performed at a draft deeper (1 meter) than the design draft, a significant reduction in turn diameter is achieved (see Figure 6). However, the speed reduction during the turn is greater for the deeper draft. At 25 kts, there is a 19 percent reduction in speed at the deeper draft compared with a 12 percent reduction at the design draft. The

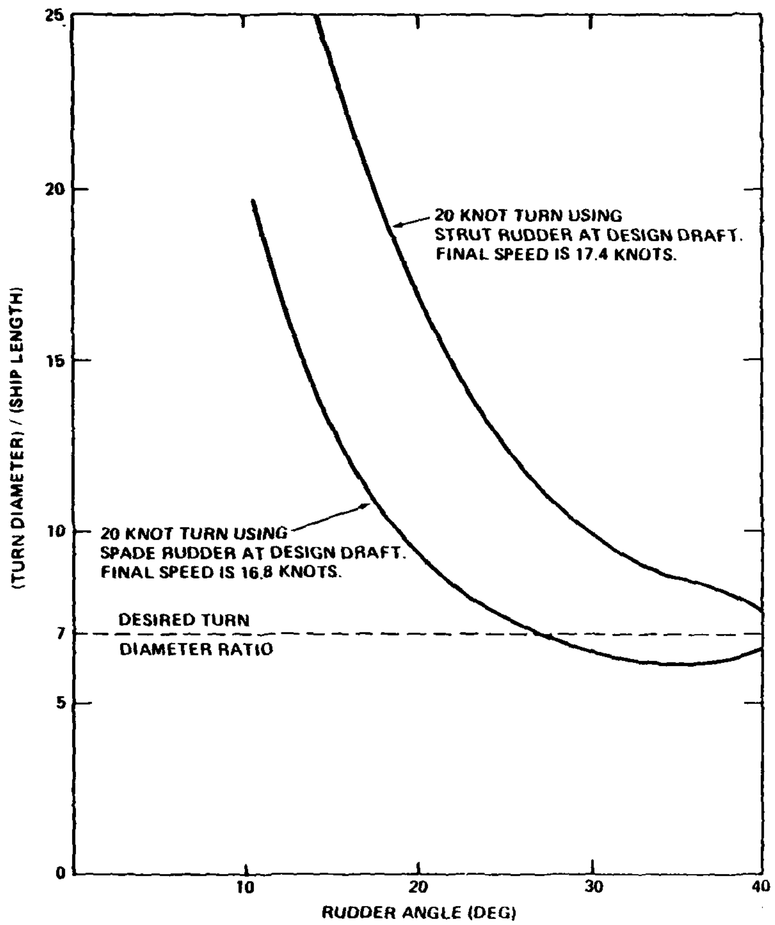

FIGURE 5 COMPARISON OF STRUT TURN DIAMETERS WITH SPADE TURN DIAMETERS

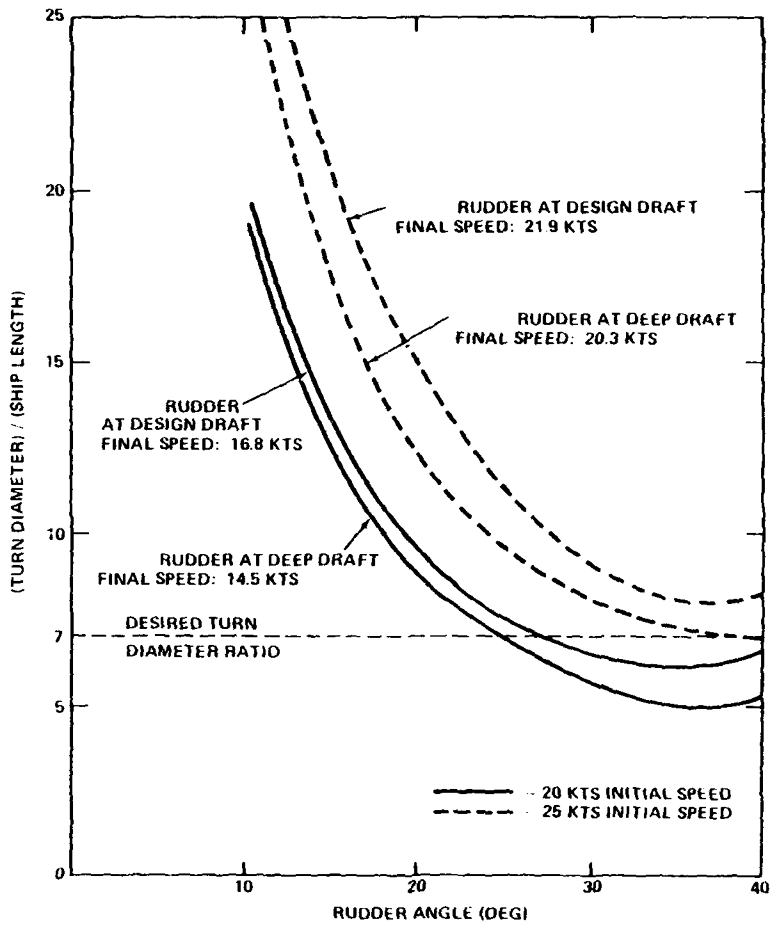

FIGURE 6 COMPARISON OF DESIGN DRAFT TURN DIAMETERS FOR SPADE RUDDERS

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percent reduction in speed is greater at the lower speeds, 27 percent for the deeper draft and 16 percent for the design draft. A deeper draft can be obtained by using the four fins to induce a net downward force.

An analysis of Figures 5 and 6 indicates that there is a small increase in turn diameter as the rudder angle increases beyond approximately 35^{o}. This increase in turn diameter is attributed to rudder stall effects. Other factors associated with the fluid flow pattern may also contribute to this effect.

The excursions in roll angle and drift angle are minor in all cases simulated. For example, the steady state roll angle in a 20 Kt turn is less than 4^{o} and the drift angle is less than 2.5^{o}. Note that the ship rolls out during a turn.

The forward turn foils are not employed in the above simulation studies. The use of these rudders may induce a sufficient turning moment so that the strut rudders would be sufficient to turn the craft within seven boat lengths. A suitable mathematical model necessary to model these forward rudders or foils is currently under development. It is expected that the relative differences between the curves appearing in Figures 5 and 6 will remain the same when the forward turn foils are employed. The net effect should be to lower all of these curves by approximately the same amount.

A comparison of SWATH turn trajectories at 20 kts with a destroyer turn trajectory at approximately the same speed is illustrated in Figure 7. The SWATH transfer is approximately 25 percent greater than the transfer for the destroyer. The SWATH turn maneuver employed only the spade rudders at

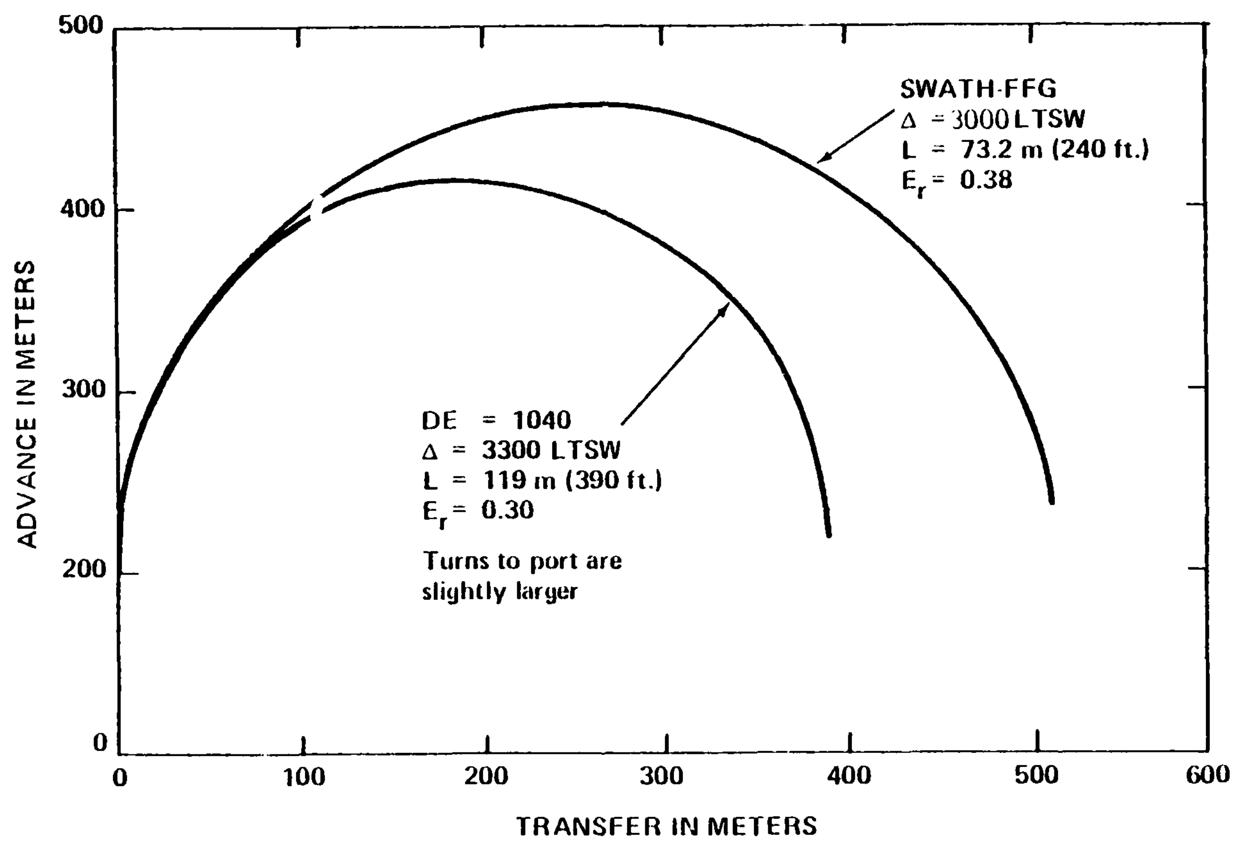

FIGURE 7 SWATH TURN TRAJECTORY COMPARED WITH A DESTROYER TURN TRAJECTORY

design draft. The forward turn foils or differential thrust capabilities are not utilized.

The SWATH turning performance at low speeds is quite impressive. Low speed turn results are discussed in the next subsection.

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LOW SPEED TURNS

Low speed turns (5 and 10 kts) are accomplished by applying a differential thrust in addition to using the aft rudders. The objective of the simulation effort is to determine the proper combination of differential thrust and rudder angle such that the advance is a minimum for a 90^{0} turn. Also, the horse power requirements are to remain less than a specified value. The desired performance can be accomplished by changing the propeller pitch/diameter ration on one side of the ship to -0.6 and the opposite pitch/diameter ratio to 1.0. The resulting predicted advance is approximately 110 meters for a 5 kt turn. At the lower speeds, the rudders are not very effective in turning the ship. In fact, the predicted turn diameter achieved by applying only a differential trust is about 15 meters larger at 5 kts.

During the low speed turns, both the drift angle and non-dimensional yaw rate exceed the range of the available data base. The drift angle may increase to 10^{0} and the non-dimensional yaw rate to values up to 1.5. The reason for such large values is that the ship is turning at a high rate at a very low speed and is, in effect, pivoting about the propeller location. Extrapolation of the data should provide reasonable results due to the extreme

linearity of the data at low speeds. Further experimental tests would be necessary to fully determine the validity of the extrapolations.

The ship advance during low speed turns is only slightly larger than the ship length (75m). Hence, in obstacle avoidance maneuvers, it is of interest to examine the predicted path swept out by SWATH, in addition to the CG trajectory. The actual path swept out by SWATH during a low speed turn is illustrated in Figure 8. These results indicate that SWATH is capable of avoiding a point obstacle approximately 112 meters in front of the craft, by a turning maneuver. A better maneuver for avoiding point obstacles at low speeds involves stopping the ship Stopping maneuvers are discussed in the following section.

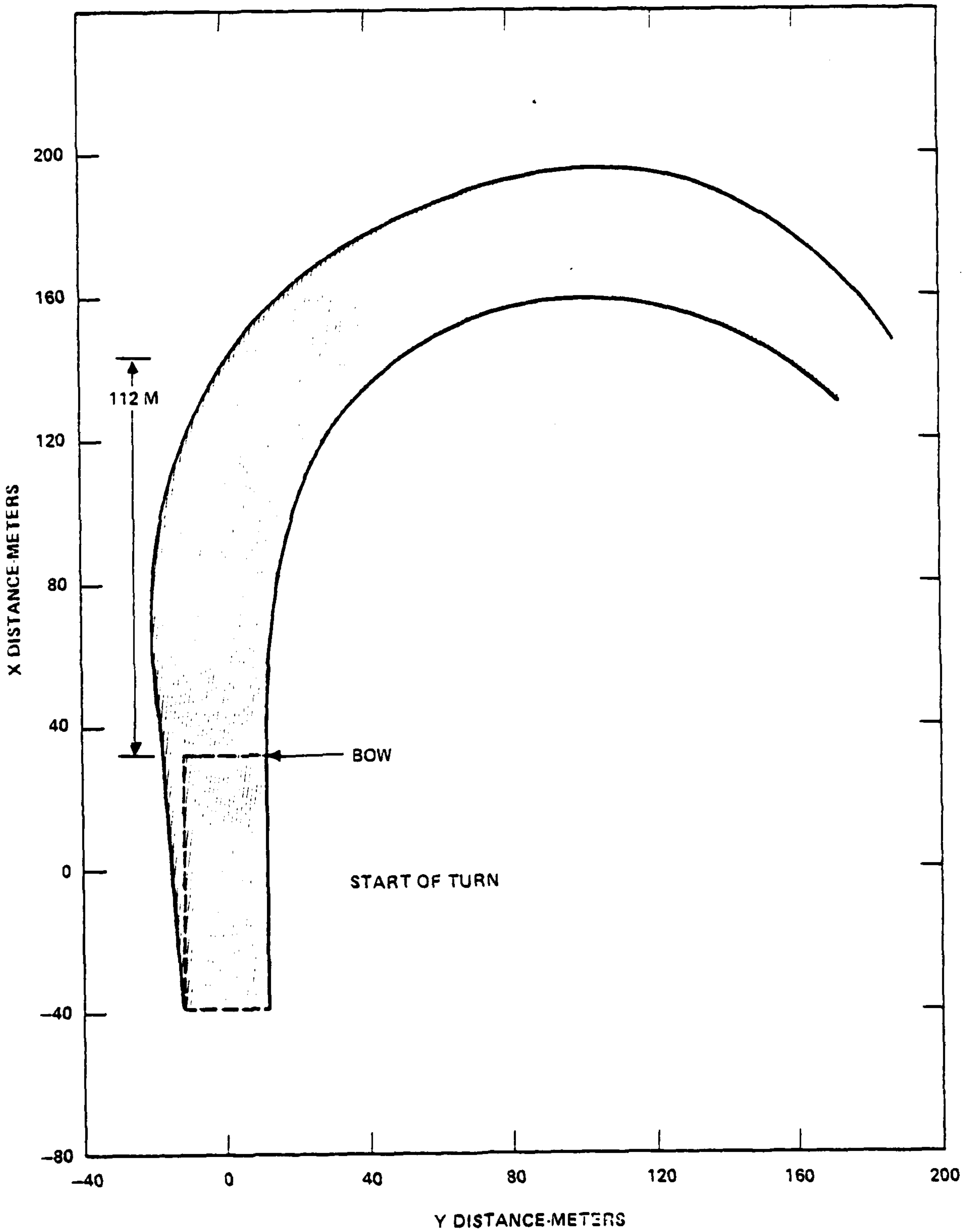

FIGURE 8 PATH SWEPT OUT BY SWATH DURING A 5 KT TURN

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STOPPING

Stopping maneuvers were performed at 5 and 10 kts by changing the propeller pitch/diameter ratio to a value of -0.6 over a period of 5 seconds. Without deflecting the rudders to increase drag, the predicted stopping distances are 27m and 80m for speeds of 5 and 10 kts respectively. However, reducing the pitch/diameter ratio to a value of -0.6 over a 5 second period results in higher horsepower requirements then desired. In order to maintain horsepower requirements, the minimum pitch value is set to be -0.15. The resulting stopping distances for 5 and 10 kts are 34m and 97m, respectively.

In order to improve stopping performance, the rudders can be deflected to their maximum values thereby increasing the drag. However, the net change in stopping distance is negligible. Such a maneuver may be more effective for high speed stopping.

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FIN EFFECTS ON TURNS

The fins can be employed to change the roll angle during turn. It was found that by forcing the ship to roll out more during a turn, the turning rate increased slightly, and vice versa. Because of stall effects, the fin angles were limited to values less than 15^{o} during this investigation. At these angles, the fins have very little effect on the turn diameters. Based on the comparisons of predicted turn diameters for different drafts, it may be more beneficial to use the fins to produce a net downward force and thus increase the draft.

OVERVIEW

The digital simulation system used to implement the mathematical model for numerical solution is a FORTRAN computer program designed to operate on the CDC 6700 digital computer located at DTNSRDC, Carderock. The final code is based on a preliminary design developed using a "top down" approach. Many features of existing digital simulation programs for AALC are incorporated in the present system, such as, the pilot action strategy (Subroutine CONTRL), hydrodynamic table lookup procedure (Subroutines HYDINT, HYDPAR), and the Runge-Kutta-Merson integration algorithm (Subroutine KUTMER)*. Several of the modules employed have been previously developed and tested by ORI (TAB2V, TAB3V, NGHBR1). The highly modular structure of the digital simulation system with well defined interfaces allowed simultaneous and on schedule development and unit testing of all force and moment subroutines by several different analysts. Also, the modular design is extremely flexible allowing various SWATH configurations to be easily modeled.

A block diagram for the complete simulation system is illustrated in Figure 9. The order in which programs are called is in a downward fashion from left to right, except the block data module which is initialized at compile time. The main program serves as a driver for the system as illustrated by the Flowchart appearing in Figure 10. Brief descriptions of major subroutines and functions are presented in Table 6. More detailed descriptions of the subroutines are presented later in this report. A listing is presented in Appendix B.

*R.F. Messalle,"First Generation Dynamic Simulation Model for an Air Cushion Vehicle", ORI, Report #814, September 28, 1973, Contract No. N00167-73-C-0213

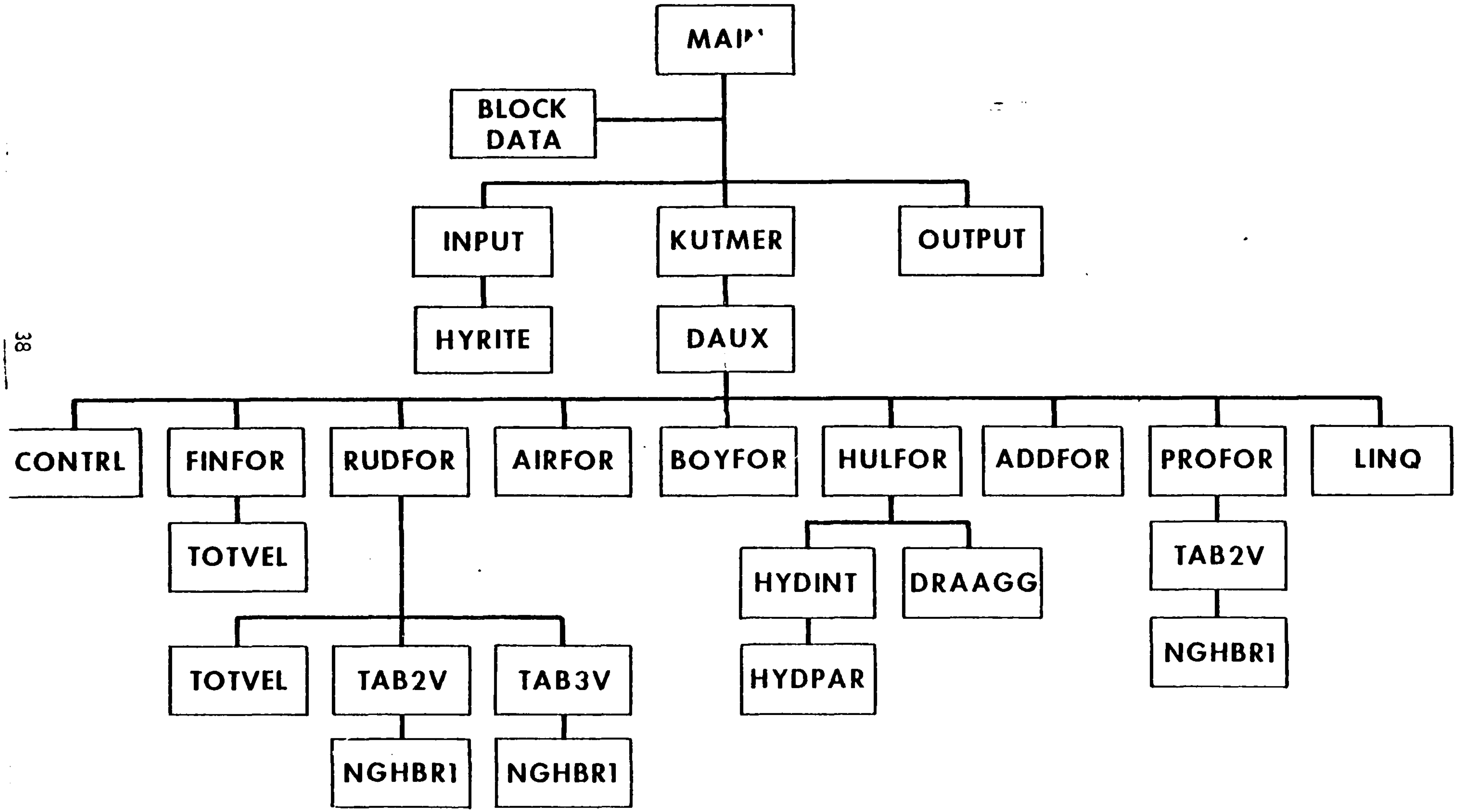

Figure 9 - SWATH Digital Simulation System Block Diagram

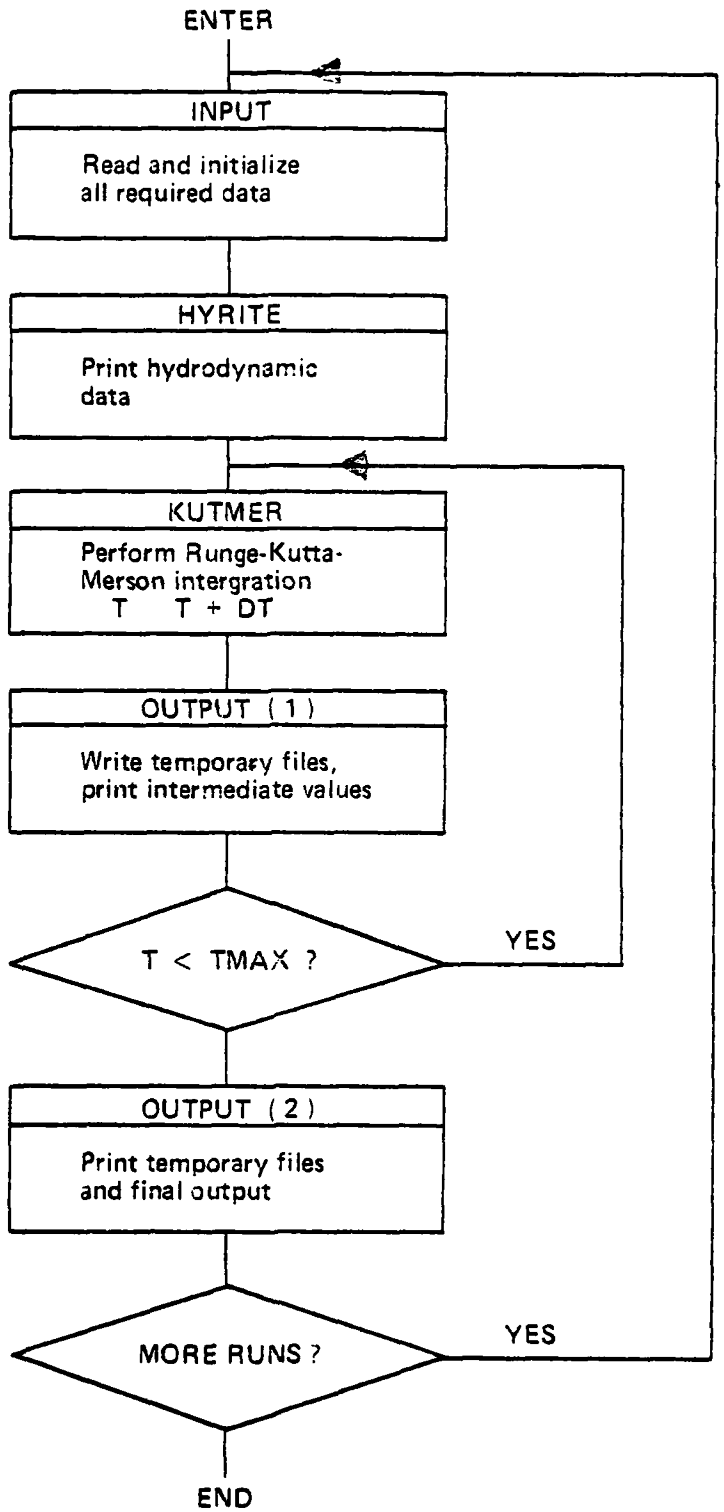

Figure 10 - Flowchart for Main Program

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TABLE 6 - SUMMARY OF SUBROUTINE DESCRIPTIONS

SWATH	Main program. Serves as a driver for the entire system.
INPUT	Reads control data, NAMELIST input and hydrodynamic data. converts variables to internal MKS units and initializes state variables.
OUTPUT	Loads output data into page arrays and writes results on line printer.
CONTRL	Control system. Changes control surfaces according to pilot action data.
TURNON	Turns on all intermediate printout options used for debugging.
DAUX	Computes mass matrix, calls all force subroutines and computes total force vector. Calls LINQ to solve simultaneous equations for state acceleration vector.
BLOCKD	Block data. Initializes all pertinent parameters. Default values can be overidden by processing in subroutine INPUT.
ADDFOR	Computer forces and moments due to rate dependent terms in operations of motion (N_r, Y_v, etc.).
HYRITE	Prints out a table of the hull hydrodynamic Y, K and N forces and moments.
DRAAGG	Computes the drag (X force) on the hull.
HULFOR	Computes the hull hydrodynamic forces and moments by calling appropriate subroutines.
BOYFOR	Computes forces and moments due to buoyancy.
FINFOR	Computes all forces and moments due to the fins.

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TABLE 6 - SUMMARY OF SUBROUTINE DESCRIPTIONS (continued)

TOTVEL	Calculates total inflow U, V, W velocities given the position vector and the ship motions.
RUDFOR	Calculates forces and moments due to aft movable rudders and fixed forward rudder.
AIRFOR	Calculates aerodynamic forces and moments.
PROFOR	Calculates propeller forces and moments.
LINQ	Solves for $\vec{X}$ where $\overleftrightarrow{A}\,\vec{X} = \vec{B}$. In this case, $\vec{X} = (\dot{u}, \dot{v}, \dot{w}, \dot{p}, \dot{q}, \dot{r})$.
EULER	Performs Euler integration on state vector and updates time.
TAB2V	Subroutine to perform 2-dimensional interpolation on data.
NGHBR1	Finds nearest neighboring points in grid arrays used by interpolation subroutines TAB2V and TAB3V.
TAB3V	Subroutine to perform 3-dimensional interpolation on data.
HYDINT	4-way interpolation subroutine to calculate hydrodynamic hull forces based on speed, roll angle, drift angle and yaw rate.
HYDPAR	Computes interpolation coefficients for HYDINT.
KUTMER	Subroutine to perform Runge-Kutta-Merson integration.

Communication between various subroutines is handled via named common blocks wherever possible. The FORTRAN symbols appearing in the common blocks are defined in a global sense. For example, the symbol U represents the ship velocity along the body x-axis in all subroutines. Definitions of all variables appearing in named common blocks are presented in Table 7. The table contains brief descriptions, the type of variable (Real, integer, etc.), and the units. Generally, descriptive notation is employed in defining the FORTRAN symbols. Some exceptions are (XC, YC, ZC) which represent (XG, YG, ZG), the CG location.

Core requirements are approximately 41,000 words base 10. Execution time is generally 5 times or more faster than real time.

A definition of required job control commands, a definition of all input data, and a user's guide are presented in the next section. Several test run setups are also presented.

TABLE 7 DEFINITION OF FORTRAN SYMBOLS APPEARING IN NAMED COMMON BLOCKS

FORTRAN Symbol	Description	Type	Units
	COMMON /AIRVAR /		
AIRFM (1-3)	Air resistance X, Y, Z forces along body axes	Real	nts
AIRFM (4-6)	Air K, M, N moments about body axes	Real	nt-m
	COMMON /ADDVAR /		
ADMTRX(6,6,6)	Matrix of rate dependent 2nd order terms for hull forces	Real	-
ADDFM (1-3)	Rate dependent X, Y, Z forces	Real	nts
ADDFM (4-6)	Rate dependent K, M, N moments	Real	nt-m
RTMTRX(6,6)	Matrix of 1st order rate dependent terms for hull forces	Real	-
	COMMON /BOYVAR /		
MSUBZ	Restoring derivative M_z due to buoyancy	Real	nt-m/m
MSUBTH	Restoring derivative M_θ due to buoyancy	Real	nt-m/rad
ZSUBZ	Restoring derivative Z_z due to buoyancy	Real	nts/m
ZSUBTH	Restoring derivative Z_θ due to buoyancy	Real	nts/rad
BUOYFM (1-3)	Buoyancy X, Y, Z forces along body axes	Real	nts
BUOYFM (4-6)	Buoyancy K, M, N moments about body axes	Real	nt-m
	COMMON /CGMOVE /		
XC,YC,ZC	X, Y, Z coordinates of center of gravity	Real	m
	COMMON /CRAFT /		
SCFACT	Ship-Model scale factor	Real	-
LENGTH	Ship length	Real	m
MASS	Ship mass	Real	kg
IXX,IYY,IZZ	Ship moments of inertia	Real	kg-m^2
IXY, IYZ,IYZ	Ship products of inertia	Real	kg-m^2
	COMMON /CONST /		
RADIAN	Number of degrees per radian, 57.29	Real	deg
RHOA	Density of air	Real	kg/m^3
RHOA2	½ of RHOA	Real	kg/m^3
RHOW	Density of water	Real	kg/m^3
RHOW2	½ of RHOW	Real	kg/m^3
FTTOM	Conversion feet to meters	Real	m/ft

TABLE 7 (Continued)

FORTRAN Symbol	Description	Type	Units
	COMMON /DOTCOE /		
XUDOT	Dimensional coefficient $X_{\dot{u}}$	Real	Kg
YVDOT	Dimensional coefficient $Y_{\dot{v}}$	Real	Kg
YPDOT	Dimensional coefficient $Y_{\dot{p}}$	Real	$Kg\text{-}m^2$
YRDOT	Dimensional coefficient $Y_{\dot{r}}$	Real	$Kg\text{-}m^2$
ZWDOT	Dimensional coefficient $Z_{\dot{w}}$	Real	Kg
ZQDOT	Dimensional coefficient $Z_{\dot{q}}$	Real	$Kg\text{-}m^2$
KVDOT	Dimensional coefficient $K_{\dot{v}}$	Real	Kg
KPDOT	Dimensional coefficient $K_{\dot{p}}$	Real	$Kg\text{-}m^2$
KRDOT	Dimensional coefficient $K_{\dot{r}}$	Real	$Kg\text{-}m^2$
MWDOT	Dimensional coefficient $M_{\dot{w}}$	Real	Kg
MQDOT	Dimensional coefficient $M_{\dot{q}}$	Real	$Kg\text{-}m^2$
NVDOT	Dimensional coefficient $N_{\dot{v}}$	Real	Kg
NPDOT	Dimensional coefficient $N_{\dot{p}}$	Real	$Kg\text{-}m^2$
NRDOT	Dimensional coefficient $N_{\dot{r}}$	Real	$kg\text{-}m^2$
	COMMON /FINVAR /		
XFIN(1-4) YFIN(1-4) ZFIN(1-4)	X, Y, Z coordinates of fin center of pressure 1 = bow starboard, 2 = bow port, 3 = aft starboard, 4 = aft port	Real	m
ARAFIN(1-4)	Areas of fins	Real	m^2
CLFIN(1-4)	Lift coefficient of fins	Real	/rad
DRFIN(1-4)	Lift/drag ratio of fins	Real	-
FINANG(1-4)	Fin angles	Real	rad
XFORFN(1-4) YFORFN(1-4) ZFORFN(1-4)	Fin X, Y, Z forces in body	Real	nts
ALIFT(1-4) DRAG(1-4)	Fin lift and drag	Real	nts
FFM (1-3)	Fin X, Y, Z forces in body system	Real	nts
FFM (4-6)	Fin K, M, N moments	Real	nt-m
FINANO(1-4)	Fin angles at time=0	Real	rad

TABLE 7 (continued)

FORTRAN Symbol	Description	Type	Units
	COMMON /HULVAR /		
HULLFM (1-3)	Hull X, Y, Z forces along body axes	Real	nts
HULLFM (4-6)	Hull K, M, N moments about body axes	Real	nt-m
HULPIK	Difference in draft from design condition, deeper draft=positive	Real	m
	COMMON /HYDRO /		
LG (4)	Number of grid points for HYDINT	Integer	-
LZ	Number of zero speed curves	Integer	-
HY (4,3213)	Data points for HYDINT array	Real	nt or nt-m
XG (4, 20)	Grid points for HYDINT array	Real	m/s, rad
IPOINT (4)	Pointer for HYDINT	Integer	-
	COMMON /INTGRL /		
DT	Step size for integration procedure	Real	s
DTMIN	Minimum step size for KUTMER	Real	s
TMAX	Maximum time for run	Real	s
AE (15)	Absolute error criterion for KUTMER integration	Real	-
EPS (15)	Relative error criterion for KUTMER integration	Real	-
NSTATE	Number of state variables	Integer	-
	COMMON /OPTION /		
IDOF	Degrees of freedom: 4, 5, 6	Integer	-
IOPTN(15)	IOPTN (2) = 0, Do not print pages 3-5 IOPTN (2) = 1, Print pages 3-5; rudder, fin, and propeller forces	Integer	-
	COMMON /PROPVR/		
PDIA	Prop diameter	Real	m
PROARM (3)	Prop X, Y, Z coordinates	Real	m
PRPMS	Prop rpm starboard	Real	rpm
PRPMP	Prop rpm port	Real	rpm
PITCHS	Pitch/Diameter ratio - starboard	Real	-
PITCHP	Pitch/Diameter ratio - port	Real	-
PROPFM (1-3)	Prop X, Y, Z forces along body axes	Real	nts
PROPFM (4-6)	Prop K, M, N moments about body axes	Real	nt-m
PTCHSO	P/D ratio - starboard Time = 0	Real	-
PTCHPO	P/D ratio - port Time = 0	Real	-

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TABLE 7 (Continued)

FORTRAN Symbol	Description	Type	Units
	COMMON /RDPRNT /		
IR (1-5)	Read units	Integer	-
IP (1-10)	Print units, 6 = main output printer	Integer	
PNT (15)	Optional-debugging output, 9 = hydro array 10 = intermediate force-moment time histories	Logical	-
	COMMON /RUDVAR /		
RUDANG (2)	Aft rudder angles, 1 = starboard, 2 = port	Real	rad
UUVEL (10)	Grid velocity array for rudder forces	Real	m/s
RALFA (10)	Grid rudder angle array for rudder forces	Real	deg
AXRUD (100)	X rudder force array	Real	nts
AYRUD (100)	Y rudder force array	Real	nts
AKRUD (100)	K rudder moment array	Real	nt-m
ANRUD (100)	N rudder moment array	Real	nt-m
ARATIO	Rudder sizing ratio, to standard rudder	Real	-
RUDANO (2)	Rudder angles at time=0	Real	rad
NUMUUV	Number of data grid velocity points	Integer	-
NUMRAL	Number of data grid rudder angle points	Integer	-
BRUDAS	Starboard bow rudder position	Real	m
BRUDAP	Port bow rudder position	Real	m
RUDFM (1-3)	Rudder X, Y, Z forces in body system	Real	nts
RUDFM (4,6)	Rudder K, M, N moments about body axes	Real	nt-m
XRUD (2)	X coordinates of aft rudder center of pressure	Real	m
YRUD (2)	Y coordinates of aft rudder center of pressure	Real	m
ZRUD (2)	Z coordinates of aft rudder center of pressure	Real	m
RUDARM	Aft rudder pitch moment arm	Real	m
BRDAPM	Bow rudder pitch moment arm	Real	m
BRSPAN	Maximum bow rudder extended length	Real	m
	COMMON /STATE /		
U,V,W	Ship velocity components in body coordinate system	Real	m/s
P,Q,R	Ship angular velocity about body axes	Real	rad/s
PHI	Roll angle	Real	rad
THETA	Pitch angle	Real	rad
PSI	Yaw angle	Real	rad
XE,YE,ZE	Ship position in fixed space coordinates	Real	m
S	Distance travelled	Real	m
SPEED	Ship speed	Real	rad
DRIFAN	Drift angle	Real	rad

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TABLE 7 (continued)

FORTRAN Symbol	Description	Type	Units
	COMMON /STATE / (Continued)		
COSPHI COSTHE COSPSI	Cosines of PHI, THETA, PSI	Real	-
SINPHI SINTHE SINPSI	Sines of PHI, THETA, PSI	Real	-
TMTRX (3,3)	Transformation matrix from fixed system to body system	Real	-
TIME	Time	Real	s
	COMMON /STATEO /		
TO	Initial time	Real	s
UO VO WO PO QO RO PHIO THETAO PSIO	Initial values of u, v w, P, Q, R, Ø, Θ, Ψ	Real	-

USER'S GUIDE

Examples of input run streams for Cases A - D are illustrated in Tables 8 - 11, respectively. Various temporary and permanent files are required. A summary of the files follows:

TAPE 8 TAPE 10 TAPE 12		Temporary files to store intermediate output
BINAR	-	Binary file for the system
TAPE 1	-	Data array for hull hydrodynamic Y force
TAPE 2	-	Data array for hull hydrodynamic K moment
TAPE 3	-	Data array for hull hydrodynamic N moment
HYDINT	-	Binary file continaing subroutines HYDINT and HYDPAR

The asterisks appearing in the card images should be replaced by account numbers and ID designator appropriate for the user. Files will be copied to appropriate ID files upon request through Code 1572, DTNSRDC.

Four types of data are read from cards: a descriptive title, Namelist/SWATHD/, pilot action data, and rate dependent coefficients. Descriptions of the data sets follow.

Title Card

The first data card is a title card. A full 80 columns may be used.

Namelist/SWATHD/Data

Program control, except for pilot actions, are governed by data located in Namelist/SWATHD/. Namelist input is used to minimize data set up errors, and to relate directly data values with FORTRAN symbols. Many of the FORTRAN symbols are initialized in the BLOCK DATA program. The data cards merely override the values. A complete description of all symbols appearing in Namelist/SWATHD/ is presented in Table 12. Default values are set up for ship parameters presented in Table 5. A few points should be noted regarding

TABLE 8 - SAMPLE RUN STREAM FOR CASE A

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```
AKRUD= 5*0.0,
6.49E+05,6.09E+05,5.70E+05,4.54E+05,-4.54E+05,-5.70E+05,-6.09E+05,
-6.49E+05,
3.11E+06,2.90E+06,2.59E+06,2.07E+06,-2.07E+06,-2.59E+06,-2.90E+06,
-3.11E+06,
4.66E+06,4.55E+06,4.43E+06,3.50E+06,-3.50E+06,-4.43E+06,-4.55E+06,
-4.66E+06,
4.99E+06,4.70E+06,4.42E+06,3.30E+06,-3.30E+06,-4.42E+06,-4.70E+06,
-4.99E+06,
6.48E+06,6.67E+06,4.96E+06,3.24E+06,-3.24E+06,-4.96E+06,-6.67E+06,
-6.48E+06,
5.69E+06,5.69E+06,5.69E+06,4.07E+06,-4.07E+06,-5.69E+06,-5.69E+06,
-5.69E+06,
ANRUD= 5*0.0,
4.02E+06,3.93E+06,3.63E+06,2.98E+06,-2.98E+06,-3.63E+06,-3.93E+06,
-4.02E+06,
1.92E+07,1.74E+07,1.56E+07,1.40E+07,-1.40E+07,-1.56E+07,-1.74E+07,
-1.92E+07,
2.10E+07,2.04E+07,1.98E+07,1.87E+07,-1.87E+07,-1.98E+07,-2.04E+07,
-2.10E+07,
2.49E+07,2.28E+07,2.07E+07,1.97E+07,-1.87E+07,-2.07E+07,-2.28E+07,
-2.49E+07,
1.95E+07,1.79E+07,1.62E+07,1.30E+07,-1.30E+07,-1.62E+07,-1.79E+07,
-1.95E+07,
4*1.83E+07,4*-1.83E+07,
TMAX=120.,PTCHPO=1.07, PTCHSO=1.07,
FRPMSO=150., FRPMPO=150., DT=3.0, NPRINT=1, $END
         2 PILOT ACTIONS
        16   17.99            7     -75.0       5.0          1
        16   17.99            8     -75.0       5.0          1
-1000.E+00
-100000.0
SWATH TEST END
 $SWATHD NRUN=-4, $END
         0 PILOT ACTIONS
-1000.E+00
-100000.0
   END OF FILE
```

TABLE 8 - SAMPLE RUN STREAM FOR CASE A (CONTINUED)

DRAFT

CASE B

```
JOBCARD,CM120000,T200,P4.
CHARGE,NAME,************,CC,K.
REQUEST,TAPE11,*PF.
REQUEST,TAPE10,*PF.
REQUEST,TAPE8,*PF.
ATTACH,TAPE1,LAKHYDATA,CY=4,ID=        .
ATTACH,TAPE2,LAKHYDATA,CY=5,ID=        .
ATTACH,TAPE3,LAKHYDATA,CY=1,ID=        .
ATTACH,BINAR,JENSWATHBINAR,ID=        .
ATTACH,HYDINT,BINARYHAF,ID=        .
LOAD(HYDINT)
BINAR.
REWIND(TAPE10).
COPY(TAPE10,OUTPUT).
REWIND(TAPE11).
COPY(TAPE11,OUTPUT).
REWIND(TAPE8).
COPY(TAPE8,OUTPUT).
  END OF FILE
SWATH TEST 5 OCT                    CASE B
 *SWATHD NRUN=1, IPOT=5, IOPTN(1)=0, IOPTN(2)=1,PNT(9)=T,PNT(10)=T,
 AXRUD= 8*0.0,
 -9.74E+04,-8.32E+04,-6.73E+04,-4.07E+04,4.07E+04,6.73E+04,8.32E+04,
 9.74E+04,
 -3.40E+05,-2.76E+05,-2.13E+05,-1.27E+05,1.27E+05,2.13E+05,2.76E+05,
 3.40E+05,
 -6.37E+05,-5.10E+05,-3.88E+05,-2.07E+05,2.07E+05,3.88E+05,5.10E+05,
 6.37E+05,
 -9.35E+05,-7.64E+05,-5.66E+05,-2.83E+05,2.83E+05,5.66E+05,7.64E+05,
 9.35E+05,
 -9.74E+05,-7.52E+05,-5.75E+05,-2.66E+05,2.66E+05,5.75E+05,7.52E+05,
 9.74E+05,
 -9.44E+05,-6.66E+05,-5.55E+05,-2.77E+05,2.77E+05,5.55E+05,6.66E+05,
 9.44E+05,
 AYRUD= 8*0.0,
 -1.84E+05,-1.67E+05,-1.59E+05,-1.20E+05,1.20E+05,1.59E+05,1.67E+05,
 1.84E+05,
 -6.51E+05,-6.72E+05,-6.94E+05,-5.31E+05,5.31E+05,6.94E+05,6.72E+05,
 6.51E+05,
 -1.23E+06,-1.37E+06,-1.31E+06,-8.76E+05,8.76E+05,1.31E+06,1.37E+06,
 1.23E+06,
 -1.67E+06,-1.81E+06,-1.95E+06,-1.44E+06,1.44E+06,1.95E+06,1.81E+06,
 1.67E+06,
 -1.95E+06,-1.95E+06,-1.77E+06,-1.15E+06,1.15E+06,1.77E+06,2*1.95E+06,
 -1.94E+06,-1.66E+06,-1.73E+06,-1.11E+06,1.11E+06,1.73E+06,1.66E+06,
 1.94E+06,
```

TABLE 9 - SAMPLE RUN STREAM FOR CASE B

DRAFT

```
AKRUP= 5*0.0,
1.04E+06,9.04E+05,7.77E+05,5.18E+05,-5.18E+05,-7.77E+05,-9.04E+05,
-1.04E+06,
3.30E+06,3.11E+06,2.80E+06,2.59E+06,-2.59E+06,-2.80E+06,-3.11E+06,
-3.30E+06,
5.60E+06,6.19E+06,5.60E+06,4.43E+06,-4.43E+06,-5.60E+06,-6.19E+06,
-5.60E+06,
8.70E+06,9.74E+06,9.74E+06,7.80E+06,-7.80E+06,-9.74E+06,-9.74E+06,
-8.70E+06,
3*9.27E+06,6.44E+06,-6.44E+06,3*-9.27E+06,
4*6.90E+06,4*-6.90E+06,
AKRUP= 8*0.0,
3*4.27E+06,3.11E+06,-3.11E+06,3*-4.27E+06,
1.32E+07,2.02E+07,1.92E+07,1.55E+07,-1.55E+07,-1.92E+07,-2.02E+07,
-1.32E+07,
3.33E+07,3.50E+07,3.38E+07,2.80E+07,-2.80E+07,-3.38E+07,-3.50E+07,
-3.33E+07,
6.63E+07,7.25E+07,6.91E+07,4.14E+07,-4.14E+07,-6.91E+07,-7.25E+07,
-6.63E+07,
3*5.50E+07,3.24E+07,-3.24E+07,3*-5.50E+07,
3*4.26E+07,3.94E+07,-3.94E+07,3*-4.26E+07,
TMAX=120.,PTCHPO=1.07, PTCHSO=1.07,
PRPMSO=150., PRPMPO=150., DT=3.0, NPRINT=1, $END
          2 PILOT ACTIONS
        16    17.99              7     -35.0        5.0               1
        16    17.99              9     -35.0        7.0               1
-1000.E+00
-100000.0
SWATH TEST END
 $SWATHD NRUN=-4, $END
          0 PILOT ACTIONS
-1000.E+00
-100000.0
   END OF FILE
```

TABLE 9 - SAMPLE RUN STREAM FOR CASE B (CONTINUED)

DRAFT

CASE C

```
JOBCARD,CM120000,T200,P4.
CHARGE,NAME,**********,CC,K.
REQUEST,TAPE11,*PF.
REQUEST,TAPE10,*PF.
REQUEST,TAPE8,*PF.
ATTACH,TAPE1,LAKEHYDATA,CY=2,ID=      .
ATTACH,TAPE2,LAKEHYDATA,CY=3,ID=      .
ATTACH,TAPE3,LAKEHYDATA,CY=4,ID=      .
ATTACH,BINAR,UFINDATHRTHMTS,ID=      .
ATTACH,HYDINT,BINARY1AB,ID=      .
LOAD(HYDINT)
BINAR.
REWIND(TAPE10).
COPY(TAPE10,OUTPUT).
REWIND(TAPE11).
COPY(TAPE11,OUTPUT).
REWIND(TAPE8).
COPY(TAPE8,OUTPUT).
  END OF FILE
SWATH TEST 5 DOF                    CASE C
 $SWATHD NRUN=1, IDOF=5, IOPTN(1)=0, IOPTN(2)=1,PNT(9)=T,PNT(10)=T,
  AXRUD= 8*0.0,
  -1.24E+05,-1.03E+05,-7.77E+04,-4.79E+04,4.79E+04,7.77E+04,1.03E+05,
  1.24E+05,
  -4.60E+05,-3.89E+05,-2.93E+05,-1.54E+05,1.54E+05,2.93E+05,3.89E+05,
  4.60E+05,
  -1.04E+06,-8.75E+05,-6.37E+05,-3.51E+05,3.51E+05,6.37E+05,8.75E+05,
  1.04E+06,
  -1.42E+06,-1.16E+06,-8.79E+05,-4.41E+05,4.41E+05,8.79E+05,1.16E+06,
  1.42E+06,
  -1.77E+06,-1.42E+06,-1.03E+06,-5.31E+05,5.31E+05,1.03E+06,1.42E+06,
  1.77E+06,
  -2.00E+06,-1.61E+06,-1.17E+06,-6.11E+05,6.11E+05,1.17E+06,1.61E+06,
  2.00E+06,
  AYRUD= 8*0.0,
  -3.01E+05,-3.01E+05,-3.01E+05,-2.10E+05,2.10E+05,3.01E+05,3.01E+05,
  3.01E+05,
  -1.06E+06,-1.06E+06,-1.06E+06,-9.07E+05,9.07E+05,1.06E+06,1.06E+06,
  1.06E+06,
  -2.04E+06,-2.04E+06,-1.89E+06,-1.32E+06,1.32E+06,1.89E+06,2.04E+06,
  2.04E+06,
  -3.23E+06,-3.23E+06,-3.12E+06,-2.26E+06,2.26E+06,3.12E+06,3.23E+06,
  3.23E+06,
  -2.66E+06,-2.79E+06,-2.79E+06,-1.91E+06,1.91E+06,2.79E+06,2.79E+06,
  2.66E+06,
  -2.39E+06,-2.51E+06,-2.51E+06,-1.71E+06,1.71E+06,2.51E+06,2.51E+06,
  2.39E+06,
```

TABLE 10 - SAMPLE RUN STREAM FOR CASE C

DRAFT

```
AKRUD= 9*0.0,
9.03E+05,9.10E+05,7.36E+05,2.33E+05,-2.77E+05,-7.36E+05,-9.10E+05,
-9.03E+05,
7.11E+06,3.21E+06,2.40E+06,2.07E+06,-2.07E+06,-2.90E+06,-3.21E+06,
-7.11E+06,
6.70E+06,7.08E+06,6.10E+06,4.09E+06,-4.09E+06,-6.06E+06,-7.08E+06,
-6.70E+06,
1.16E+07,1.20E+07,1.04E+07,7.88E+06,-7.88E+06,-1.04E+07,-1.20E+07,
-1.16E+07,
1.55E+07,1.62E+07,1.36E+07,1.04E+07,-1.04E+07,-1.36E+07,-1.62E+07,
-1.55E+07,
1.70E+07,1.79E+07,1.54E+07,1.14E+07,-1.14E+07,-1.54E+07,-1.79E+07,
-1.70E+07,
ANRUD= 9*0.0,
5.13E+06,6.09E+06,7.09E+06,4.01E+06,-4.01E+06,-7.09E+06,-6.09E+06,
-5.13E+06,
2.49E+07,2.64E+07,2.74E+07,2.38E+07,-2.38E+07,-2.74E+07,-2.64E+07,
-2.49E+07,
4.66E+07,4.90E+07,5.13E+07,3.73E+07,-3.73E+07,-5.13E+07,-4.90E+07,
-4.66E+07,
7.87E+07,7.67E+07,7.46E+07,5.60E+07,-5.60E+07,-7.46E+07,-7.67E+07,
-7.87E+07,
7.45E+07,7.45E+07,7.45E+07,5.83E+07,-5.83E+07,-7.45E+07,-7.45E+07,
-7.45E+07,
6.69E+07,6.69E+07,6.69E+07,5.24E+07,-5.24E+07,-6.69E+07,-6.69E+07,
-6.69E+07,
TMAX=120.,PTCHP0=1.07, PTCHS0=1.07,
PRPMS0=150., PRPMP0=150., DT=3.0, NPRINT=1, $END
      2 PILOT ACTIONS
     16    17.[illegible]         7     -35.0       5.0             1
     16    17.[illegible]         8     -35.0       5.0             1
-1000.E+00
-100000.0
SWATH TEST END
 $SWATHD NRUN=-4. $END
      0 PILOT ACTIONS
-1000.E+00
-100000.0
   END OF FILE
```

TABLE 10 - SAMPLE RUN STREAM FOR CASE C (CONTINUED)

CASE D

```
JOBCARD,CM120000,T200,P4.
CHARGE,NAME,***********,CC,K.
REQUEST,TAPE11,*PF.
REQUEST,TAPE10,*PF.
REQUEST,TAPE8,*PF.
ATTACH,TAPE1,LAKHYDATE,CY=7,ID=     .
ATTACH,TAPE2,LAKHYDATC,CY=1,ID=     .
ATTACH,TAPE3,LAKHYDATC,CY=2,ID=     .
ATTACH,BINAR,JE,SWATHBINUP,ID=     .
ATTACH,HYDINT,BINARY1AB,ID=     .
LOAD(HYDINT)
BINAR.
REWIND(TAPE10).
COPY(TAPE10,OUTPUT).
REWIND(TAPE11).
COPY(TAPE11,OUTPUT).
REWIND(TAPE8).
COPY(TAPE8,OUTPUT).
  END OF FILE
SWATH TEST 5 DOF                   CASE D
 $SWATHD NRUN=1, IDOF=5, IOPTN(1)=0, IOPTN(2)=1,PNT(9)=T,PNT(10)=T,
 AXRUD= 8*0.0,
 -1.56E+05,-1.28E+05,-1.01E+05,-6.77E+05,6.77E+05,1.01E+05,1.28E+05,
 1.56E+05,
 -5.46E+05,-4.00E+05,-3.54E+05,-2.13E+05,2.13E+05,3.54E+05,4.00E+05,
 5.46E+05,
 -1.04E+06,-8.30E+05,-6.22E+05,-3.13E+05,3.14E+05,6.22E+05,8.30E+05,
 1.04E+06,
 -1.53E+06,-1.12E+06,-7.09E+05,-4.25E+05,4.25E+05,7.09E+05,1.12E+06,
 1.53E+06,
 -1.77E+06,-1.31E+06,-8.41E+05,-4.47E+05,4.47E+05,8.41E+05,1.31E+06,
 1.77E+06,
 -1.67E+06,-1.19E+06,-7.22E+05,-3.85E+05,3.85E+05,7.22E+05,1.19E+06,
 1.67E+06,
 AYRUD= 8*0.0,
 -4.25E+05,-3.90E+05,-3.54E+05,-3.00E+05,3.00E+05,3.54E+05,3.90E+05,
 4.25E+05,
 -1.30E+06,-1.21E+06,-1.13E+06,-8.39E+05,8.39E+05,1.13E+06,1.21E+06,
 1.30E+06,
 -2.07E+06,-1.91E+06,-1.73E+06,-1.37E+06,1.37E+06,1.73E+06,1.91E+06,
 2.07E+06,
 -2.62E+06,-2.48E+06,-2.27E+06,-1.76E+06,1.76E+06,2.27E+06,2.48E+06,
 2.62E+06,
 -2.17E+06,-1.90E+06,-1.64E+06,-1.15E+06,1.15E+06,1.64E+06,1.90E+06,
 2.17E+06,
 -1.39E+06,-1.31E+06,-1.22E+06,-9.38E+05,9.38E+05,1.22E+06,1.31E+06,
 1.39E+06,
```

TABLE 11 - SAMPLE RUN STREAM FOR CASE D

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```
AKRUD= 8*0.0,
5.66E+05,5.12E+05,4.57E+05,3.59E+05,-3.59E+05,-4.57E+05,-5.12E+05,
-5.66E+05,
2.70E+06,2.44E+06,2.19E+06,1.71E+06,-1.71E+06,-2.19E+06,-2.44E+06,
-2.70E+06,
8.05E+06,7.23E+06,6.41E+06,4.66E+06,-4.66E+06,-6.41E+06,-7.23E+06,
-8.05E+06,
9.95E+06,9.02E+06,8.00E+06,6.22E+06,-6.22E+06,-8.00E+06,-9.02E+06,
-9.95E+06,
8.75E+06,7.94E+06,7.13E+06,5.51E+06,-5.51E+06,-7.13E+06,-7.94E+06,
-8.75E+06,
6.13E+06,5.56E+06,4.99E+06,3.85E+06,-3.85E+06,-4.99E+06,-5.56E+06,
-6.13E+06,
ANRUD= 8*0.0,
5.91E+06,5.37E+06,5.22E+06,3.92E+06,-3.92E+06,-5.22E+06,-5.37E+06,
-5.91E+06,
2.95E+07,2.72E+07,2.49E+07,1.87E+07,-1.87E+07,-2.49E+07,-2.72E+07,
-2.95E+07,
4.55E+07,4.08E+07,3.61E+07,3.03E+07,-3.03E+07,-3.61E+07,-4.08E+07,
-4.55E+07,
4.77E+07,4.49E+07,4.13E+07,3.30E+07,-3.30E+07,-4.13E+07,-4.49E+07,
-4.77E+07,
4.54E+07,4.05E+07,3.56E+07,2.92E+07,-2.92E+07,-3.56E+07,-4.05E+07,
-4.54E+07,
4.27E+07,3.81E+07,3.35E+07,2.74E+07,-2.74E+07,-3.35E+07,-3.81E+07,
-4.27E+07,
TMAX=120.,PITCHFD=1.07, PITCHRD=1.07,
PRPMSO=150., PRPMPO=150., DT=3.0, NPRINT=1, $END
        2 PILOT ACTIONS
       15    17.99             7     -35.0       5.0              1
       16    17.99             9     -35.0       5.0              1
-1000.E+00
-100000.0
SWATH TEST END
 $SWATHD NRUN=-4, $END
        0 PILOT ACTIONS
-1000.E+00
-100000.0
   END OF FILE
```

TABLE 11 - SAMPLE RUN STREAM FOR CASE D (CONTINUED)

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TABLE 12-DEFINITION OF FORTRAN SYMBOLS APPEARING IN NAMELIST /SWATHD/

FORTRAN Symbol	Description	Type	Units
AE	Absolute error criterion for range-KUTMER integration	Real	-
AKRUD	K rudder moment array	Real	nt-m
ANRUD	N rudder moment array	Real	nt-m
ARAFIN	Areas of fins	Real	m^2
ARATIO	Rudder sizing ratio, to standard rudder	Real	-
AXRUD	X rudder force array	Real	nts
AYRUD	Y rudder force array	Real	nts
BRDARM	Aft rudder pitch moment arm	Real	m
BRSPAN	Maximum bow rudder extended length	Real	m
BRUDPO	Port bow rudder position, initial time		
BRUDSO	Starboard bow rudder position, initial time		
CLFIN	Lift coefficient of fins	Real	/rad
DT	Step size for integration procedure	Real	s
DTMIN	Minimum step size for KUTMER	Real	s
EPS	Relative error criterion for KUTMER integration	Real	-
FINANO	Fin angles at initial time	Real	rad
HULPIK	Difference in draft from design condition, deeper draft=positive	Real	m
IDOF	Degrees of freedom	Integer	-
IOPTN	Integration technique and optional pages 3-5	Integer	-
IXX	Ship moments of inertia	Real	$kg\text{-}m^2$
IXY	Ship products of inertia	Real	$kg\text{-}m^2$
IXZ	Ship products of inertia	Real	$kg\text{-}m^2$
IYY	Ship moments of inertia	Real	$kg\text{-}m^2$
IYZ	Ship products of inertia	Real	$kg\text{-}m^2$
IZZ	Ship moments of inertia	Real	$kg\text{-}m^2$
KPDOT	Dimensional coefficient $K_{\dot{p}}$	Real	$kg\text{-}m^2$
KRDOT	Dimensional coefficient $K_{\dot{r}}$	Real	$kg\text{-}m^2$
KVDOT	Dimensional coefficient $K_{\dot{v}}$	Real	kg
LENGTH	Ship length	Real	m
MASS	Ship mass	Real	kg
MQDOT	Dimensional coefficient $M_{\dot{q}}$	Real	$kg\text{-}m^2$
MSUBTH	Restoring derivative M_Θ due to buoyancy	Real	nt-m/rad
MSUBZ	Restoring derivative M_z due to buoyancy	Real	nt-m/m
MWDOT	Dimensional coefficient $M_{\dot{w}}$	Real	kg
NPDOT	Dimensional coefficient $N_{\dot{p}}$	Real	$kg\text{-}m^2$
NPRINT	Number of DT increments in print loop	Integer	-
NRDOT	Dimensional coefficient $N_{\dot{r}}$	Real	$kg\text{-}m^2$

TABLE 12 (continued)

FORTRAN Symbol	Description	Type	Units
NRUN	Simulation run number	Integer	-
NUMRAL	Number of data grid rudder angle points	Integer	-
NUMUUV	Number of data grid velocity points	Integer	-
NVDOT	Dimensional coefficient $N_{\dot{v}}$	Real	kg
PDIA	Prop diameter	Real	m
PHIO	Initial Ø value	Real	-
PNT	Optional-debugging output, 9 = hydro array 10 = intermediate force-moment time histories	Logical	-
PO	Initial P value	Real	-
PROARM	Prop X, Y, Z coordinates	Real	m
PRPMPO	Initial port propeller rpm's	Real	rpm
PRPMSO	Initial starboard propeller rpm's	Real	rpm
PSIO	Initial Ψ value	Real	-
PTCHPO	P/D ratio - port at T=0	Real	-
PTCHSO	P/D ratio - starboard at T=0	Real	-
QO	Initial Q value	Real	-
RALFA	Grid rudder angle array for rudder forces	Real	deg
RO	Initial R value	Real	-
RUDANO	Rudder angles at initial time	Real	rad
RUDARM	Aft rudder pitch moment arm	Real	m
SCFACT	Ship-Model scale factor	Real	-
THETAO	Initial Θ value	Real	-
TITLE	Title of run		
TMAX	Maximum time for run	Real	s
TO	Initial time	Real	s
UO	Initial U value	Real	-
UUVEL	Grid velocity array for rudder forces	Real	m/s
VO	Initial V value	Real	-
XC	X coordinate of center of gravity	Real	m
XFIN	X coordinate of fin center of pressure 1 = bow starboard, 2 = bow port, 3 = aft starboard, 4 = aft port	Real	m
XRUD	X coordinate of aft rudder center of pressure	Real	m
XUDOT	Dimensional coefficient $X_{\dot{u}}$	Real	kg
YC	Y coordinates of center of gravity	Real	m
YFIN	Y coordinates of fin center of pressure	Real	m
YPDOT	Dimensional coefficient $Y_{\dot{p}}$	Real	kg-m^2
YRDOT	Dimensional coefficient $Y_{\dot{r}}$	Real	kg-m^2
YRUD	Y coordinates of aft rudder center of pressure	Real	m

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TABLE 12 (continued)

FORTRAN Symbol	Description	Type	Units
YVDOT	Dimensional coefficient $Y_{\dot{v}}$	Real	kg
ZC	Z coordinates of center of gravity	Real	m
ZFIN	Z coordinates of fin center of pressure 1 = bow starboard, 2 = bow port, 3 = aft starboard, 4 = aft port	Real	m
ZQDOT	Dimensional coefficient $Z_{\dot{q}}$	Real	$kg\text{-}m^2$
ZRUD	Z coordinates of aft rudder center of pressure	Real	m
ZSUBTH	Restoring derivative Z_θ due to buoyancy	Real	nts/rad
ZSUBZ	Restoring derivative Z_z due to buoyancy	Real	nts/m
ZWDOT	Dimensional coefficient $Z_{\dot{w}}$	Real	kg

the Namelist input data. The FORTRAN variable NRUN should be assigned a unique value for all runs to be submitted at one time. Only IDOF=5, and IDOF=6 modes of operation have been tested. During the course of this study, several values of DT were used. A value of 3.0 results in a very few interval halving operations in KUTMER, and, hence, can be considered optimum. A smaller value of DT may be desirable due to print out considerations. Currently, state variable time histories are printed at integer multiples of DT, every NPRINT*DT seconds. If a sampling interval of 3.0 seconds is undesirable, DT should be changed.

Pilot Action Data

The control system allows the programmer to read in up to ten control actions via pilot action data cards. The system is designed so that the programmer can choose from twelve controlled items and sixteen state controlling variables. The system allows for both single instance or constant monitoring of the controlling variables. For example, assume the aft rudder is to be turned to -20° if $\psi < 10^{\circ}$. If single instance is chosen, this action will be performed the first time $\psi < 10^{\circ}$. Under constant monitoring, however, this action will be performed every time $\psi < 10^{\circ}$.

In the present system, the controlled item must have a numerical end value read in. There is no provision for reducing a variable by ten percent, for example. All pilot action data items are in 10 column fields right justified*. The first card of data indicates how many pilot action cards are to be read. The pilot action cards have the following format:

*Floating point numbers need not be right justified provided the decimal point appears explicitly.

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	J1	CV1(I)	J2	CV2(I)	CV3(I)	JACT(I)
Columns	1-10	11-20	21-30	31-40	41-50	51-60

where

J1 = index of state vector controlling variable

CV1 = numerical value of J1 when control is to be activated

J2 = controlled item

CV2 = final value of controlled item

CV3 = rate of change of controlled item

JACT = 1 = single instance, 0 = constant monitoring.

The definitions of possible values for J1 and J2 are given in Table 13. The units for CV1, CV2, and CV3 are MKS units. Angles are in degrees. If a controlling variable condition is to be less than some CV1 value, e.g. If YE <- 100 m, the index of the controlling variable should be assigned a negative value. CONTRL is called during each call to DAUX. CONTRL checks to see whether the controlled item needs to be changed, and if so performs the changes at the desired rate. When the control item reaches its final value, CONTRL checks JACT and if JACT=1, the control item is turned off. Otherwise, that controlled item is continuously monitored for possible further actions. If multiple actions have been programmed for a controlled item, an error message will be printed out and the last action performed.

<u>Rate Dependent Coefficients</u>

The pilot action data is followed by rate coefficients. Currently, values are not available. The values -1000.E + 00 and - 100000. indicate to the subroutine INPUT that rate coefficients are not to be read.

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TABLE 13 PILOT ACTION DATA DESCRIPTIONS

INDEX	STATE VECTOR CONTROLLING VARIABLE	CONTROLLED ITEM
1	u	Starboard propeller RPM
2	v	Port propeller RPM
3	w	Starboard propeller P/D ratio
4	p	Port propeller P/D ratio
5	q	Forward starboard rudder position
6	r	Forward port rudder position
7	Roll angle	Aft starboard rudder angle
8	Pitch angle	Aft port rudder angle
9	Yaw angle	Bow starboard fin angle
10	XE	Bow port fin angle
11	YE	Aft starboard fin angle
12	ZE	Aft port fin angle
13	Distance travelled	
14	Speed	
15	Drift angle	
16	Time	

DESCRIPTION OF OUTPUT

An example of printout is presented in Appendix C. A brief description of the output follows. The title card and all data read via Namelist is printed at the beginning of the output. This output appears as the FORTRAN symbol followed by the assigned value. After the Namelist is printed the requested pilot actions are listed. The hull hydrodynamic data are next printed if PNT(9)=.TRUE..

Following the above output, up to 5 pages of time histories are printed. These contain time histories of the state variables and time histories of the control surface deflections. Pages 2-4 are printed if IOPTN(2) is set to 1. These pages consist of time histories associated with the rudder, fin, and propulsion subsystems. The printout starting with the Namelist and ending with page five is repeated for each run.

Intermediate forces and moments are printed following the paged output for all runs (if PNT(10)=.TRUE.). These data contain a time history of each force component computed in DAUX. A complete table of X, Y, Z, K, M, N forces and moments is given at each time step. This option is useful for debugging purposes, as unrealistic ship motions are often caused by improper programming of a specific force subroutine.

A time history of time steps used by KUTMER is printed at the end of each computer job submitted if PNT(10)=.TRUE.. Optimum integration time steps can be selected based on an examination of this output.

The next section contains descriptions of various subroutines. Sufficient detail is presented so that new force and moment models can be easily developed.

SUBROUTINE DESCRIPTIONS

This section contains a short description of the main program and the associated subroutines. Each description contains the purpose of the subroutine, how to call it, parameter descriptions and clarifying remarks. Except for the main program, the subroutines are listed in alphabetical order.

Program SWATH

Purpose - Main driver for simulation. Calls INPUT to initialize variables, calls KUTMER in integration loop, calls OUTPUT, and checks to see if all runs have been completed.

Subroutines called - INPUT, KUTMER, OUTPUT

Remarks -

1) SWATH calls INPUT to initialize variables
2) SWATH calls KUTMER in a do-loop of order NPRINT, thus obtaining output values in increments of DT x NPRINT, e.g., DT = 1, NPRINT = 3, output is in 3 sec intervals
3) SWATH automatically terminates the run when time > TMAX
4) Each run must have a different NRUN value, a repeated value or a negative value stops the program and starts intermediate printout.
5) SWATH calls OUTPUT in the integration loop to load values into output arrays. OUTPUT is also called outside the loop at the end of a run to print out the last page of output that will not necessarily be a full forty lines.
6) Output is printed one page (40 line) at a time. The data is loaded into page arrays

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Subroutine ADDFOR

Purpose. To calculate the hull forces due to first and second order rate dependent terms

Usage. CALL ADDFOR

Remarks.

1) The first order equation used is

ADDFM(J) = RTMRX(J,K) · Variable (K) · dimensionalizing factor

2) The second order equation used is

ADDFM(J) = ADMTRX(J,K,L) · Variable (K) · Variable (L) · dimensionalizing factor

3) RTMTDX and ADMTRX are the derivatives of the forces and moments with respect to the volocities, e.g. N_v, X_u, K_{pr}.

4) The dimensionalizing factors are:

½p(ship length)^2 for J=1,2,3 (X,Y,Z)

½p(length)^3 for J=4,5,6 (K,M,N)

Subroutine AIRFOR

Purpose. To calculate the aerodynamic forces and moments

Usage. Call AIRFOR

Remarks.

1) Estimates show that the aerodynamic forces can be neglected and all forces and moments are set equal zero.

Subroutine BOYFOR

Purpose. to calculate forces and moments due to bouyancy and gravitation

Usage. CALL BOYFOR

Remarks. 1) Equations used for buoyancy are

$$Z = Z_h h + Z_\theta \theta$$

$$K = \frac{\text{beam}}{2}^{2} \cdot \tan\phi \cdot Z_z$$

$$M = M_h h + M_\theta \theta$$

2) $Z_h, Z_\theta, M_h, M_\theta$ are assumed constant for small motions and given in the body coordinate system

3) The gravitational moments are calculated as weight · moment arm, where the moment arm is dependent on the distance X_G, Y_G, or Z_G and the ship orientation.

Program BLOCKD

Purpose. Initializes all constants and ship state variables appearing in named common blocks

Remarks. 1) All variables have been initialized to perform straight ahead flight at 20 knots.

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Subroutine CONTRL

Purpose. to determine whether a pilot action is necessary and if so, to perform the operation at a specified rate.

Usage. CALL CONTRL (T,Y)

Description of Parameters.

T = time

Y = state vector, see INPUT for description

Remarks. 1) Control actions are read in on cards. See users guide section description of parameters and Table 13.

2) Controlled items are fin and rudder angles, bow rudder position, and propeller pitch and rpm.

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Subroutine DAUX

Purpose. to compute the right hand side of the differential equations of motion. (See Figure 11 for Flow Chart).

Usage. CALL DAUX(T,Y,F)

Description of Parameters.

T	-	time
Y(1)	-	U, velocity along body x axis (m/sec)
Y(2)	-	V, velocity along body y axis (m/sec)
Y(3)	-	W, velocity along body z axis (m/sec)
Y(4)	-	P, angular velocity about body x axis (rad/sec)
Y(5)	-	Q, angular velocity about body y axis (rad/sec)
Y(6)	-	R, angular velocity about body z axis (rad/sec)
Y(7)	-	ϕ, roll angle (rad)
Y(8)	-	θ, pitch angle (rad)
Y(9)	-	ψ, yaw angle (rad)
Y(10)	-	X_E, x position in fixed coordinate systems (m)
Y(11)	-	Y_E, y position in fixed coordinate systems (m)
Y(12)	-	Z_E, z position in fixed coordinate systems (m)
Y(13)	-	S, distance traveled (m)
F(1-13)	-	derivatives corresponding to the above variables

Subroutines Called. CONTRL, FINFOR, RUDFOR, HULFOR, AIRFOR, BOYFOR, PROFOR, ADDFOR, LINQ

Remarks. 1) The 6x6 mass/inertia matrix is computed from the ship mass, moments and products of inertia, and added mass-inertia terms.

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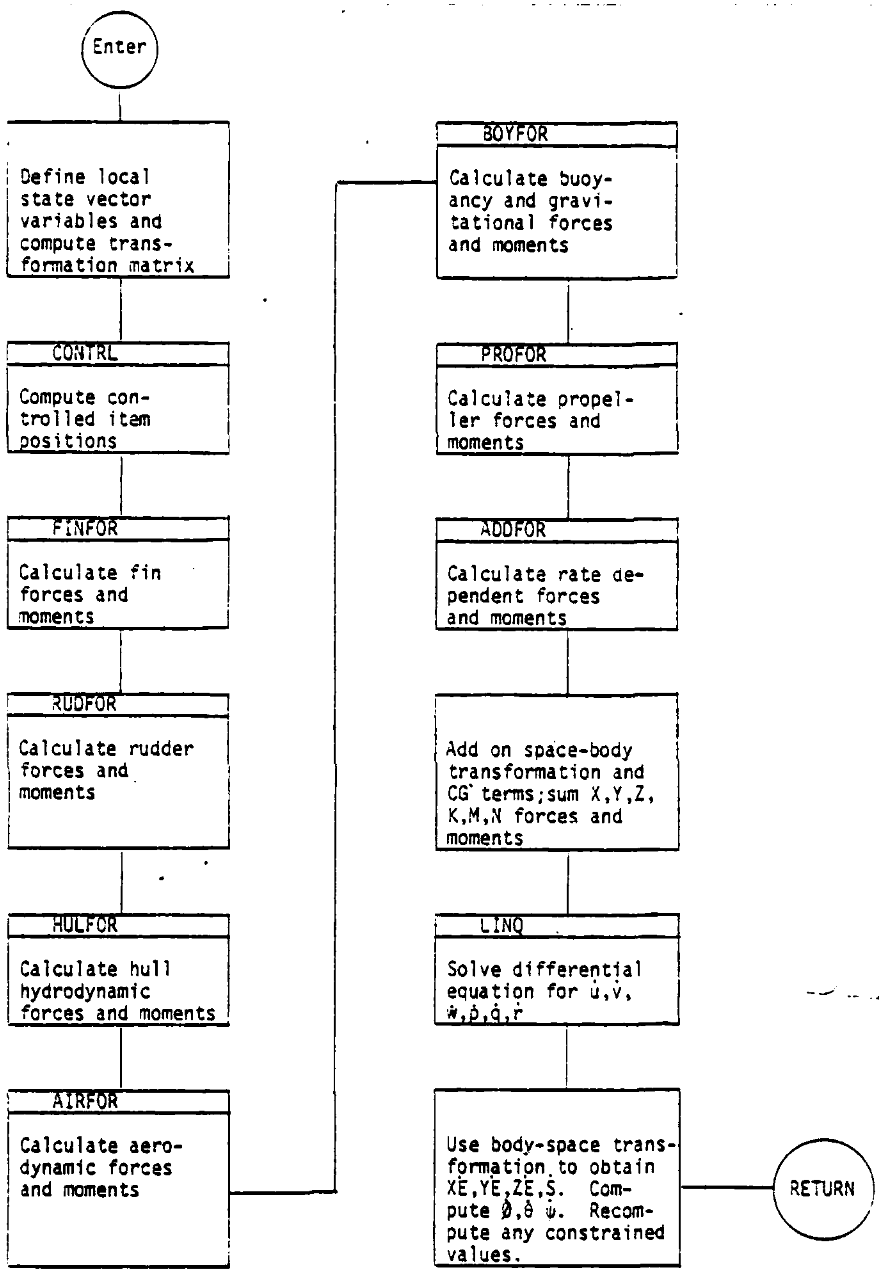

FIGURE 11 FLOWCHART FOR SUBROUTINE DAUX

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2) The force vector is determined by

A - calling the separate force subroutines

B - calculating the terms due to space-body transformation

C - calculating terms due to center of gravity not origin

D - summing all forces

3) DAUX computes the space-body transformation matrix based on the ship orientation. This matrix is used to calculate the fixed space acceleration terms from the body axis acceleration terms returned from LINQ.

4) If degrees of freedom are less than 6, DAUX uses a constraint equation to evaluate the appropriate terms.

Function DRAAGG

Purpose. calculates hull drag at a given speed

Usage. DRAAGG(V)

Description of Parameters.

V - Speed (m/s)

Remarks. 1) Drag is calculated as $\frac{\text{EHP} \times 1450.1}{V(\text{m/s})}$

2) EHP is computed by interpolating a data base of EHP values for speeds from 0 to 28 knots with grid points at integer values of speed.

Subroutine EULER

Purpose. performs EULER integration on state vector Y

Usage. CALL EULER (T,DT,Y,NSTATE)

Subroutines Called. DAUX

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Description of Parameters.

T - time

DT - step size

Y - state vector (See INPUT)

NSTATE - number of variables in Y

Remarks. 1) DAUX is called to obtain the time derivatives of state vector Y

2) $Y_{new} = Y_{old} + DT \cdot F$ where F is the time derivative vector

3) EULER has no error check and is a purely mechanical subroutine. If too large a DT is used, there will be major errors in the integration after many time steps.

Subroutine FINFOR

Purpose. to calculate the total fin forces and moments

Usage. CALL FINFOR

Subroutines Called. TOTVEL

Remarks. 1) TOTVEL is used to calculate the total inflow velocity at each fin

2) Fin left is calculated theoretically as Lift = $\frac{1}{2}\rho AU^2 C_L$

where ρ = density of water

A = fin chord $\cdot$ span

U = total inflow velocity $\sqrt{u^2 + w^2}$

C_L = lift coefficient

3) Fin drag approximated as Lift/7

4) Center of pressure assumed at quarter chord and half span.

5) Effects of side flow (v) have been ignored

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Subroutine HULFOR

Purpose. to calculate the hydrodynamic Y,K,N hull forces as a function of speed, roll angle, yaw rate, and drift angle.

Usage. CALL HULFOR

Subroutines called. DRAAGG, HYDINT

Remarks. 1) Equations used, at a given speed

$$Y = Y_\beta \beta + Y_{r'} r' + Y_\phi \phi$$

$$K = K_\beta \beta + K_{r'} r' + K_\phi \phi$$

$$N = N_\beta \beta + N_{r'} r' + N_\phi \phi$$

2) HYDINT and HYDPAR perform a four-dimensional interpolation to obtain the Y,K,N forces as a function of speed, drift angle, yaw rate, and roll angle.

3) DRAAGG calculates the X force

Subroutine HYDINT

Purpose. performs a 4 dimensional interpolation for hull hydrodynamic forces based on data curves. Independent variables are speed, drift angle, yaw rate, and roll angle.

Usage. CALL HYDINT

Subroutine Called. HYDPAR

Remarks. 1) Hydrodynamic values must be stored in array HY(4,3213) in a linear fashion. The first index represents the X,Y,K,N data. Array XG(4,20) contains the data base grid values. The first index represents the four independent variables: 1 = roll angle, 2 = drift angle, 3 = yaw rate, 4 = speed. Array LG(4) contains the number of base grid values for

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each parameter. The indexing of HY(Y,3213) is as follows: for Array HY(I,J), the Jth value corresponds to the I force at the location

$$J = IR + LG(1)\left[ID-1 + LG(2)\ \{IY-1 + LG(3)(IS-1)\}\right]$$

where IR, ID, IY, and IS represent the grid point index in the XG array for roll, drift, yaw and speed, respectively and LG(k) equals the number of grid points for that parameter.

Subroutine HYDPAR

Purpose. to recompute the interpolation coefficients for HYDINT if the data cell is not entered when HYDINT is called

Usage. CALL HYDPAR

Remarks. 1) HYDINT will call HYDPAR automatically if necessary.

2) The coefficients calculated by HYDPAR are based on the cell grid points and the data base grid points need not be uniformly spaced.

Subroutine HYRITE

Purpose. optional listing of hydrodynamic hull coefficients in tabular form

Usage. CALL HYRITE

Remarks. 1) Called from INPUT if PNT(9) = .TRUE.

Subroutine INPUT

Purpose. Reads in NAMELIST data, hydrodynamic hull data, pilot control data and rate dependent terms and converts initial conditions to MKS units.

Usage. Call INPUT(Y, TIMEE)

Description of Parameters.

Y - Ship state vector

Y(1) - velocity along body x axis (m/sec)

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2 = V, velocity along body y axis (m/sec)

3 = W, velocity along body z axis (m/sec)

4 = P, angular velocity about body x axis (rad/sec)

5 = Q, angular velcoity about body y axis (rad/sec)

6 = R, angular velocity about body z axis (rad/sec)

7 = ϕ, roll angle (rad)

8 = θ, pitch angle (rad)

9 = ψ, yaw angle (rad)

10 = XE, X coordinate in fixed space

11 = YE, Y coordinate in fixed space

12 = ZE, Z coordinate in fixed space

13 = S - distance travelled

TIMEE = time

Remarks. 1) All initial conditions and values that may change due to configuration changes can be read in via NAMELIST.

2) Hull data read in from tapes. These must be attached in the following manner. Tape 1 = Y data, Tape 2 - K data, Tape 3 = N data.

3) Pilot action data is described in the User's Guide section and Table 13.

4) Rate dependent terms are read in as follows

Example - for first order terms

N_v = RTMTRX(6,2), K_p = RTMTRX(4,4)$\cdots$1 = X,U 2 = Y,V

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3 = Z,W   4 = K,p   5 = M,q   6 = N,r

for second order terms

N_{vr} = ADMTRX (6,2,6) and (6,6,2) as in the above correspondence

Subroutine KUTMER

Purpose. Performs Runge-Kutta-Merson integration.

Usage. CALL KUTMER (ND, T, H, YO, EPSE, A, HCX, FIRST)

Subroutines Called. DAUX

Description of Parameters.

- ND - number of variables in YO
- T - time
- H - step size
- YO - state vector, enter with initial values at T, returns values at T + H
- EPSE - relative error criterion for YO components
- A - absolute error criterion for YO components
- HCX - smallest step size to be used by KUTMER
- FIRST = 0. when KUTMER is entered for first time or with changed step size
  - = 1. when entered with same H to continue integration in a sequence
  - = 2. When error criterion cannot be met and H < HCX

Remarks. 1) KUTMER calls DAUX five times to predict endpoint value of Y

2) If error criteria are not met KUTMER automatically halves the interval and repeats. If halved interval becomes less than

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H/32, KUTMER stops and prints out error message

Subroutine LINQ

Purpose. Solves for X where AX = B
Usage. CALL LINQ (A,B,N,KS)
Description of Parameters.

A,B = input matrix, LINQ solves for X and replaces B by X

N - number of equations, dimension of B

KS - error code, 1 = singular matrix, 0 = normal

Remarks. 1) X represents the acceleration matrix used by KUTMER

2) A = mass-inertia matrix obtained from DAUX

3) B = force matrix obtained from DAUX

Subroutine NGHBR1

Purpose. To find the nearer neighbor less than or equal to the desired value in the Array V

Usage. CALL NGHBR1 (V, ARG, II, N, IER, RATIO)

Description of parameters.

V - variable array

ARG - search argument

II - Location such that V(II). LE. ARG. LE.V(II+1)

N - number of points in V

IER - 0 in range, otherwise out of range

RATIO = (ARG - V(II))/ (V(II+1) - V(II))

Remarks. RATIO will be used in the interpolation in TAB2V or TAB3V

Subroutine OUTPUT

Purpose. prints out paged output

Usage. call OUTPUT (IOPT)

Description of parameters.

IOPT - SWATH sets = 2 when the run terminates. If IOPT = 1, the pages

are printed out even if not full, which may happen if run terminates. Otherwise, OUTPUT does not print until a full page of 40 lines is reached.

<u>Remarks</u>. 1) Page 1 contains a time history of some ship state values and the position in fixed space

Page 2 contains a time history of the control surface values

Page 3 contains a detailed time history of propeller forces and moments

Page 4 contains a detailed time history of rudder forces and moments

Page 5 contains a detailed time history of fin forces and moments

2) IOPTN (2) controls pages 3-5. If 1, pages are printed. If 0, they are not

3) Output is in MKS system with angles in degrees

4) Time history values are loaded into page arrays and printed out one page (40 lines) at a time.

5) See sample run for page listings

<u>Subroutine PROFOR</u>

<u>Purpose</u>. to calculate propeller thrust, pitch, and yaw moments.

<u>Usage</u>. CALL PROFOR

<u>Subroutines Called</u>. TAB2V

<u>Remarks</u>. 1) Thrust = $K_T \rho n^2 D^4$

where K_T = thrust coefficient obtained through table look up

n = revolutions/sec

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D = propeller diameter

2) K_T is obtained through interpolation using TAB2V and propeller K_T vs. J curves as data

3) Propeller Y and Z forces have been neglected.

4) Propellers are operated independently so that differential thrut can be applied for low speed turns.

Subroutine RUDFOR

Purpose. to calculate the rudder forces and moments

Usage. Call RUDFOR

Subroutines called. TAB2V, TAB3V

Remarks. 1) RUDFOR first calculates the aft rudder contribution, and then the fixed forward rudder contribution

2) The aft rudder data is read in as four linear arrays AXRUD, AYRUD, AKRUD, ANRUD. These arrays contain rudder force data based on rudder deflection angle and speed.

3) TAB2V performs a two-way interpolation on the rudder data to obtain the aft rudder X, Y, K, and N forces. The M moment is calculated as the X force times the moment arm.

4) For the fixed forward rudder, an array BYRUD has been constructed that contains the rudder Y force based on speed, drift angle, and yaw rate. TAB3V performs a 3-way interpolation to obtain the rudder Y force. The X force is approximated as Y/7 and K, M, N moments are calculated using the X and Y forces times the appropriate moment arms. This portion of modeling is still under development.

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5) Different aft rudder sizes are handled by an ARATIO term in the aft rudder equations. ARATIO is a ratio of actual rudder size to a standard size rudder used in the model tests.

Subroutine TAB2V

Purpose. performs a two-dimensional interpolation on a given data base.

Usage. CALL TAB2V (V1, V2, OB, N1, N2, ARGI, ARG2, ID, KEY, II, JJ,)
VAL, IER)

Subroutines Called. NGHBR2

Description of Parameters.

V1, V2	- variable arrays starting with smallest and increasing monotonically. Values must be unique
OB	- observed function values stored columnwise according to V1, V2
N1, N2	- number of V1's and V2's
ARG1, ARG2	- arguments 1 and 2
ID	- unit for printout
KEY	- if = 0, do not perform search, use previous V's and ratios
II	- closest point to ARG1 S.T. V(II).L E. ARG1
JJ	- closest point to ARG2 S.T. V(JJ).L E. ARG2
VAL	- interpolated value
IER	- 0 - in range, otherwise out of range

determined by NGHBR1

Subroutine TAB3V

Purpose. performs a 3-dimensional interpolation on a given data base.

Usage. CALL TAB3V (V1, V2, V3, OB, N1, N2, N3, ARG2, ARG2, ARG3, ID, KEY,

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II, JJ, KK, VAL, IER)

Subroutines Called. NGHBR2

Description of parameters

V1, V2, V3	-	Variable data arrays starting with smallest and increasing monotorically. Values must be unique.
OB	-	Observed function values stored columnwise according to V1, V2, V3
N1, N2, N3	-	number of V1's, V2 s, V3's
ARG1, ARG2, ARG3	-	arguments 1, 2, and 3
ID	-	unit for printout
KEY	-	if = 0, do not perform search, use previous v's and ratios
II	-	closest point in V1 to ARG1 S.T. V(II).LE. ARG1
JJ	-	closest point in V2 to ARG2 S.T. V(JJ).LE. ARG2
KK	-	closest point in V3 to ARG3 S.T. V(KK).LE. ARG3
VAL	-	Interpolated value
IER	-	0, in range, otherwise out of range

Subroutine TOTVEL

Purpose. to calculate inflow velocity at a given point based on the radius vector and the ship velocities.

Usage. CALL TOTVEL (UU, VV, WW, PP, QQ, RR, XDV, YDV, ZDV, UTOT, VTOT, WTOT)

Description of Parameters.

UU, VV, WW	-	ship U, V, W velocities
PP, QQ, RR	-	ship P, Q, R angular velocities (radius/sec)
SDV, YDV, ZDV	-	X, Y, Z coordinates of point in question

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UTOT, VTOT, WTOT - U, V, W inflow velocities at that point

Remarks. 1) All velocities are in the body system

2) UTOT = UU - RR·YDV + QQ·ZDV

VTOT = VV - PP·ZDV + RR·XDV

WTOT = WW - QQ·XDV + PP·YDV

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RECOMMENDATIONS

The current digital simulation can be used to develop optimum maneuvering strategies for various missions to be performed by SWATH. The results of such studies if they are conducted may provide useful information to the Navy allowing a complete evaluation of SWATH potential capabilities.

Another major area of mathematical modeling that should be pursued is the modeling of sea way effects. Due to the small waterplane area, it is expected that seaway effects would have a relatively mild influence on craft dynamics as compared with conventional craft. Taking these effects into account would lead to a more meaningful comparison of SWATH performance with conventional craft performance.

There are many minor refinements that can be made regarding the mathematical model. The mathematical model and digital simulation program are designed to accept refined data bases and improved theoretical estimates when they become available.

It is recommended that the basic data base approach employed in this study be extended to other high performance craft that are currently employing theoretical models. These theoretical models are usually very complex and require extensive computational efforts. However, one could limit these computational efforts by using the theoretical expressions offline to generate a data base, a one time effort, that could then be used in the approach presented in this paper to carry out many different simulated maneuvers.

CONCLUSIONS

This study represents a fairly extensive dynamic simulation model development based primarily on experimental model data. The

final product has proved to be a useful evaluation tool in studying SWATH performance during a variety of maneuvers for several different configurations. The success of the approach used is based on a well planned program of model experiments that provided a sufficient data base for mathematical model development.

The results of the predictions indicate that significant improvements in performance can be achieved when the spade rudder configuration are considered or when a deeper draft is used during turn maneuvers. The results also indicate that the SWATH has very good turning performance characteristics at low speeds when differential thrust is used.

ACKNOWLEDGEMENTS

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NOTATION

$\vec{S}$	State vector
A	Generalized mass/inertia matrix
$\vec{F}$	Time rate of change of state vector
$\overline{M}$	Ship mass
$X_{\dot{u}}$	Coefficient used in representing X as a function of $\dot{u}$
$Y_{\dot{v}}$	Coefficient used in representing Y as a function of $\dot{v}$
$Z_{\dot{w}}$	Coefficient used in representing Z as a function of $\dot{w}$
$K_{\dot{p}}$	Coefficient used in representing K as a function of $\dot{p}$
$M_{\dot{q}}$	Coefficient used in representing M as a function of $\dot{q}$
$N_{\dot{r}}$	Coefficient used in representing N as a function of $\dot{r}$
X_G	Location of CG along body x axis
Y_G	Location of CG along body y axis
Z_G	Location of CG along body z axis
$Y_{\dot{p}}$	Coefficient used in representing Y as a function of $\dot{p}$
$Y_{\dot{r}}$	Coefficient used in representing Y as a function of $\dot{r}$
$Z_{\dot{q}}$	Coefficient used in representing Z as a function of $\dot{q}$
$K_{\dot{v}}$	Coefficient used in representing K as a function of $\dot{v}$
$K_{\dot{r}}$	Coefficient used in representing K as a function of $\dot{r}$
$M_{\dot{w}}$	Coefficient used in representing M as a function of $\dot{w}$
$N_{\dot{v}}$	Coefficient used in representing N as a function of $\dot{v}$
$N_{\dot{p}}$	Coefficient used in representing N as a function of $\dot{p}$
I_{xx}	Moment of inertia about x axis.
I_{yy}	Moment of inertia about y axis
I_{zz}	Moment of inertia about z axis

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I_{xy}	Product of inertia about xy axis
I_{xz}	Product of inertia about xz axis
I_{yz}	Product of inertia about yz axis
p	Angular velocity about x axis
q	Angular velocity about y axis
r	Angular velocity about z axis
u	Velocity along body x axis
v	Velocity along body y axis
w	Velocity along body z axis
ϕ	Roll angle
θ	Pitch angle
ψ	Yaw angle
XE	Displacement along fixed x axis
YE	Displacement along fixed y axis
ZE	Displacement along fixed z axis
T	Transformation matrix from body to fixed coordinate system
EHP	Effective horsepower
X	Total force along body x axis
Y	Total force along body y axis
Z	Total force along body z axis
K	Total moment about body x axis
M	Total moment about body y axis
N	Total moment about body z axis
ρ	Density of water
L	Ship length

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F	Fin force or moment
AR	Fin aspect ratio
V_f	Inflow velocity at fin
C_L	Fin lift coefficient
α	Fin angle of attach
A	Fin area
X_f	Fin x position
Y_f	Fin y position
Z_f	Fin z position
K_T	Thrust coefficient
n	Propeller revolutions per second
D	Propeller diameter
J	Advance coefficient
V_a	Propeller speed of advance
Z_θ	Coefficient to represent buoyancy Z as a function of θ
Z_z	Coefficient to represent buoyancy Z as a function of z
M_θ	Coefficient to represent buoyancy Z moment as a function of θ
M_z	Coefficient to represent buoyancy Z moment as a function of z

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F	Fin force or moment
AR	Fin aspect ratio
V_f	Inflow velocity at fin
C_L	Fin lift coefficient
α	Fin angle of attach
A	Fin area
X_f	Fin x position
Y_f	Fin y position
Z_f	Fin z position
K_T	Thrust coefficient
n	Propeller revolutions per second
D	Propeller diameter
J	Advance coefficient
V_a	Propeller speed of advance
Z_θ	Coefficient to represent buoyancy Z as a function of θ
Z_z	Coefficient to represent buoyancy Z as a function of z
M_θ	Coefficient to represent buoyancy Z moment as a function of θ
M_z	Coefficient to represent buoyancy Z moment as a function of z

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APPENDIX A

DATA BASES USED IN THE SIMULATION MODEL

ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NON-DIMENSIONAL	SPEED KTS	Y FORCE NTS	K MOMENT NT-M	N MOMENT NT-M
-6.00	-4.00	-.30	5.00	-.244044E+06	.323669E+07	.155360E+07
0.00	-4.00	-.30	5.00	-.244044E+06	.297774E+07	.129467E+07
6.00	-4.00	-.30	5.00	-.244044E+06	.271881E+07	.103574E+07
-6.00	0.00	-.30	5.00	-.134511E+06	.258934E+07	.414295E+07
0.00	0.00	-.30	5.00	-.134511E+06	.233041E+07	.388401E+07
6.00	0.00	-.30	5.00	-.134511E+06	.207147E+07	.362509E+07
-6.00	4.00	-.30	5.00	-.247784E+05	.194201E+07	.673229E+07
0.00	4.00	-.30	5.00	-.247784E+05	.168307E+07	.647335E+07
6.00	4.00	-.30	5.00	-.247784E+05	.142414E+07	.621442E+07
-6.00	-4.00	0.00	5.00	-.109733E+06	.906269E+06	-.233041E+07
0.00	-4.00	0.00	5.00	-.109733E+06	.647335E+06	-.258934E+07
6.00	-4.00	0.00	5.00	-.109733E+06	.388401E+06	-.284928E+07
-6.00	0.00	0.00	5.00	0.	.258934E+06	.258934E+06
0.00	0.00	0.00	5.00	0.	0.	0.
6.00	0.00	0.00	5.00	0.	-.258934E+06	-.258934E+06
-6.00	4.00	0.00	5.00	.109733E+06	-.388401E+06	.284828E+07
0.00	4.00	0.00	5.00	.109733E+06	-.647335E+06	.258934E+07
6.00	4.00	0.00	5.00	.109733E+06	-.906269E+06	.233041E+07
-6.00	-4.00	.30	5.00	.247784E+05	-.142414E+07	-.621442E+07
0.00	-4.00	.30	5.00	.247784E+05	-.168307E+07	-.647335E+07
6.00	-4.00	.30	5.00	.247784E+05	-.194201E+07	-.673229E+07
-6.00	0.00	.30	5.00	.134511E+06	-.207147E+07	-.362509E+07
0.00	0.00	.30	5.00	.134511E+06	-.233041E+07	-.388401E+07
6.00	0.00	.30	5.00	.134511E+06	-.258934E+07	-.414295E+07
-6.00	4.00	.30	5.00	.244044E+06	-.271881E+07	-.103574E+07
0.00	4.00	.30	5.00	.244044E+06	-.297774E+07	-.129467E+07
6.00	4.00	.30	5.00	.244044E+06	-.323669E+07	-.155360E+07
-6.00	-4.00	-.30	10.00	-.101237E+07	.321078E+07	.414295E+07
0.00	-4.00	-.30	10.00	-.101237E+07	.279649E+07	.517868E+07
6.00	-4.00	-.30	10.00	-.101237E+07	.238219E+07	.621442E+07
-6.00	0.00	-.30	10.00	-.516906E+06	.932163E+06	.145003E+08
0.00	0.00	-.30	10.00	-.516906E+06	.517868E+06	.155360E+08
6.00	0.00	-.30	10.00	-.516906E+06	.103574E+06	.165718E+08
-6.00	4.00	-.30	10.00	-.212386E+05	-.134646E+07	.243577E+08
0.00	4.00	-.30	10.00	-.212386E+05	-.176075E+07	.258934E+08
6.00	4.00	-.30	10.00	-.212386E+05	-.217505E+07	.269291E+08
-6.00	-4.00	0.00	10.00	-.495568E+06	.269291E+07	-.113931E+08
0.00	-4.00	0.00	10.00	-.495568E+06	.227862E+07	-.103574E+08
6.00	-4.00	0.00	10.00	-.495568E+06	.186433E+07	-.932163E+07
-6.00	0.00	0.00	10.00	0.	.414295E+06	-.103574E+07
0.00	0.00	0.00	10.00	0.	0.	0.
6.00	0.00	0.00	10.00	0.	-.414295E+06	.103574E+07
-6.00	4.00	0.00	10.00	.495568E+06	-.186433E+07	.932163E+07
0.00	4.00	0.00	10.00	.495568E+06	-.227862E+07	.103574E+08
6.00	4.00	0.00	10.00	.495568E+06	-.269291E+07	.113931E+08
-6.00	-4.00	.30	10.00	.212386E+05	.217505E+07	-.269291E+08

TABLE A1 Hydrodynamic Hull Data for Strut Rudder Configuration at Design Dfart

ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NON-DIMENSIONAL	SPEED KTS	Y FORCE NT	K MOMENT NT-M	N MOMENT NT-M
0.00	-4.00	.30	10.00	.212386E+05	.176075E+07	-.259934E+08
6.00	-4.00	.30	10.00	.212386E+05	.134646E+07	-.240577E+08
-6.00	0.00	.30	10.00	.516906E+06	-.103574E+06	-.145718E+09
0.00	0.00	.30	10.00	.516906E+06	-.517369E+07	-.155369E+09
6.00	0.00	.30	10.00	.516906E+06	-.932163E+06	-.145903E+09
-6.00	4.00	.30	10.00	.101037E+07	-.238019E+07	-.621442E+07
0.00	4.00	.30	10.00	.101037E+07	-.278649E+07	-.517969E+07
6.00	4.00	.30	10.00	.101037E+07	-.321078E+07	-.414295E+07
-6.00	-4.00	-.30	15.00	-.278934E+07	.179120E+08	.915642E+07
0.00	-4.00	-.30	15.00	-.210262E+07	.160799E+08	.915642E+07
6.00	-4.00	-.30	15.00	-.191590E+07	.151476E+08	.915642E+07
-6.00	0.00	-.30	15.00	-.124246E+07	.114170E+08	.314605E+08
0.00	0.00	-.30	15.00	-.955738E+06	.104868E+08	.314605E+08
6.00	0.00	-.30	15.00	-.669016E+06	.955467E+07	.314605E+08
-6.00	4.00	-.30	15.00	-.127432E+06	.592602E+07	.547646E+08
0.00	4.00	-.30	15.00	.159290E+06	.482385E+07	.547646E+08
6.00	4.00	-.30	15.00	.446011E+06	.396169E+07	.547646E+08
-6.00	-4.00	0.00	15.00	-.143361E+07	.652514E+07	-.233041E+08
0.00	-4.00	0.00	15.00	-.114689E+07	.559298E+07	-.233041E+08
6.00	-4.00	0.00	15.00	-.860164E+06	.466081E+07	-.233041E+08
-6.00	0.00	0.00	15.00	-.286721E+06	.932163E+06	0.
0.00	0.00	0.00	15.00	0.	0.	0.
6.00	0.00	0.00	15.00	.286721E+06	-.932163E+06	0.
-6.00	4.00	0.00	15.00	.860164E+06	-.466081E+07	.233041E+08
0.00	4.00	0.00	15.00	.114689E+07	-.559298E+07	.233041E+08
6.00	4.00	0.00	15.00	.143361E+07	-.652514E+07	.233041E+08
-6.00	-4.00	.30	15.00	-.446011E+06	-.396169E+07	-.547646E+08
0.00	-4.00	.30	15.00	-.159290E+06	-.482385E+07	-.547646E+08
6.00	-4.00	.30	15.00	.127432E+06	-.592602E+07	-.547646E+08
-6.00	0.00	.30	15.00	.669016E+06	-.955467E+07	-.314605E+08
0.00	0.00	.30	15.00	.955738E+06	-.104868E+08	-.314605E+08
6.00	0.00	.30	15.00	.124246E+07	-.114170E+08	-.314605E+08
-6.00	4.00	.30	15.00	.191590E+07	-.151476E+08	-.915642E+07
0.00	4.00	.30	15.00	.210262E+07	-.160799E+08	-.915642E+07
6.00	4.00	.30	15.00	.278934E+07	-.179120E+08	-.815642E+07
-6.00	-4.00	-.30	20.00	-.410613E+07	.285863E+08	.176075E+08
0.00	-4.00	-.30	20.00	-.410613E+07	.310721E+08	.331436E+08
6.00	-4.00	-.30	20.00	-.410613E+07	.335579E+08	.486796E+08
-6.00	0.00	-.30	20.00	-.297341E+07	.294142E+08	.102538E+09
0.00	0.00	-.30	20.00	-.297341E+07	.269291E+08	.870019E+08
6.00	0.00	-.30	20.00	-.297341E+07	.244434E+08	.714658E+08
-6.00	4.00	-.30	20.00	-.184069E+07	.252720E+08	.156336E+09
0.00	4.00	-.30	20.00	-.184068E+07	.277577E+08	.171932E+09
6.00	4.00	-.30	20.00	-.184068E+07	.302435E+08	.187469E+09
-6.00	-4.00	0.00	20.00	-.113273E+07	.165718E+07	-.693843E+08
0.00	-4.00	0.00	20.00	-.113273E+07	.414295E+07	-.539583E+08

TABLE A1 (Continued)

DRAFT

ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NONDIMENSIONAL	SPEED KTS	Y FORCE NT	K MOMENT NT-M	N MOMENT NT-M
6.00	-4.00	0.00	20.00	-.113273E+07	.662871E+07	-.383222E+08
-6.00	0.00	0.00	20.00	0.	-.248577E+07	-.155360E+08
0.00	0.00	0.00	20.00	0.	0.	0.
6.00	0.00	0.00	20.00	0.	.248577E+07	.155360E+08
-6.00	4.00	0.00	20.00	.113273E+07	-.662871E+07	.383222E+08
0.00	4.00	0.00	20.00	.113273E+07	-.414295E+07	.538593E+08
6.00	4.00	0.00	20.00	.113273E+07	-.165718E+07	.693943E+08
-6.00	-4.00	.30	20.00	.184068E+07	-.302435E+08	-.187468E+09
0.00	-4.00	.30	20.00	.184068E+07	-.277577E+08	-.171932E+09
6.00	-4.00	.30	20.00	.184068E+07	-.252720E+08	-.156396E+09
-6.00	0.00	.30	20.00	.297341E+07	-.244434E+08	-.714658E+08
0.00	0.00	.30	20.00	.297341E+07	-.269291E+08	-.870195E+08
6.00	0.00	.30	20.00	.297341E+07	-.294149E+08	-.102538E+09
-6.00	4.00	.30	20.00	.410613E+07	-.335572E+08	-.486796E+09
0.00	4.00	.30	20.00	.410613E+07	-.310721E+08	-.331436E+09
6.00	4.00	.30	20.00	.410613E+07	-.285863E+08	-.176075E+09
-6.00	-4.00	-.30	25.00	-.641583E+07	.291301E+08	.339951E+08
0.00	-4.00	-.30	25.00	-.579637E+07	.271881E+08	.485501E+08
6.00	-4.00	-.30	25.00	-.517691E+07	.252461E+08	.631152E+08
-6.00	0.00	-.30	25.00	-.358402E+07	.279354E+08	.111665E+09
0.00	0.00	-.30	25.00	-.296456E+07	.259934E+08	.126230E+09
6.00	0.00	-.30	25.00	-.234510E+07	.239514E+08	.140795E+09
-6.00	4.00	-.30	25.00	-.752201E+06	.265407E+08	.219476E+09
0.00	4.00	-.30	25.00	-.132741E+06	.245987E+08	.233041E+09
6.00	4.00	-.30	25.00	.486718E+06	.226567E+08	.247606E+09
-6.00	-4.00	0.00	25.00	-.345127E+07	.323668E+07	-.222453E+09
0.00	-4.00	0.00	25.00	-.283192E+07	.129467E+07	-.776802E+08
6.00	-4.00	0.00	25.00	-.221236E+07	-.647335E+06	-.631152E+09
-6.00	0.00	0.00	25.00	-.619460E+06	.194201E+07	-.145653E+08
0.00	0.00	0.00	25.00	0.	0.	0.
6.00	0.00	0.00	25.00	.619460E+06	-.194201E+07	.145653E+09
-6.00	4.00	0.00	25.00	.221236E+07	.647335E+06	.631152E+08
0.00	4.00	0.00	25.00	.283192E+07	-.129467E+07	.776802E+08
6.00	4.00	0.00	25.00	.345127E+07	-.323668E+07	.222453E+09
-6.00	-4.00	.30	25.00	-.486718E+06	-.226567E+08	-.247606E+09
0.00	-4.00	.30	25.00	.132741E+06	-.245987E+08	-.233041E+09
6.00	-4.00	.30	25.00	.752201E+06	-.265407E+08	-.219476E+09
-6.00	0.00	.30	25.00	.234510E+07	-.239514E+08	-.140795E+09
0.00	0.00	.30	25.00	.296456E+07	-.259934E+08	-.126230E+09
6.00	0.00	.30	25.00	.358402E+07	-.279354E+08	-.111665E+09
-6.00	4.00	.30	25.00	.517691E+07	-.252461E+08	-.631152E+08
0.00	4.00	.30	25.00	.579637E+07	-.271881E+08	-.485501E+08
6.00	4.00	.30	25.00	.641583E+07	-.291301E+08	-.339951E+08
-6.00	-4.00	-.30	28.00	-.715996E+07	.341347E+08	.207704E+09
0.00	-4.00	-.30	28.00	-.688244E+07	.316687E+08	.406009E+08
6.00	-4.00	-.30	28.00	-.660493E+07	.292026E+08	.605313E+09

TABLE A1 (Continued)

DRAFT

ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NON-DIMENSIONAL	SPEED KTS	Y FORCE NTS	K MOMENT NT-M	N MOMENT NT-M
-6.00	0.00	-.30	28.00	-.305270E+07	.328867E+08	.117743E+09
0.00	0.00	-.30	28.00	-.277518E+07	.304507E+08	.138043E+09
6.00	0.00	-.30	28.00	-.249766E+07	.280146E+08	.158343E+09
-6.00	4.00	-.30	28.00	.105457E+07	.316697E+08	.215195E+09
0.00	4.00	-.30	28.00	.133209E+07	.292326E+08	.235495E+09
6.00	4.00	-.30	28.00	.160960E+07	.267966E+08	.255795E+09
-6.00	-4.00	0.00	28.00	-.438478E+07	.365408E+07	-.117743E+09
0.00	-4.00	0.00	28.00	-.410726E+07	.121903E+07	-.974421E+08
6.00	-4.00	0.00	28.00	-.382975E+07	-.121803E+07	-.771416E+08
-6.00	0.00	0.00	28.00	-.277518E+06	.243605E+07	-.203094E+07
0.00	0.00	0.00	28.00	0.	0.	0.
6.00	0.00	0.00	28.00	.277518E+06	-.243605E+07	.203094E+07
-6.00	4.00	0.00	28.00	.382975E+07	.121803E+07	.771416E+08
0.00	4.00	0.00	28.00	.410726E+07	-.121903E+07	.974421E+08
6.00	4.00	0.00	28.00	.438478E+07	-.365408E+07	.117743E+09
-6.00	-4.00	.30	28.00	-.160960E+07	-.267966E+08	-.255795E+09
0.00	-4.00	.30	28.00	-.133209E+07	-.292326E+08	-.235495E+09
6.00	-4.00	.30	28.00	-.105457E+07	-.316697E+08	-.215195E+09
-6.00	0.00	.30	28.00	.249766E+07	-.280146E+08	-.158343E+09
0.00	0.00	.30	28.00	.277518E+07	-.304507E+08	-.138043E+09
6.00	0.00	.30	28.00	.305270E+07	-.328867E+08	-.117743E+09
-6.00	4.00	.30	28.00	.661493E+07	-.292326E+08	-.609013E+08
0.00	4.00	.30	28.00	.689244E+07	-.316697E+08	-.406009E+08
6.00	4.00	.30	28.00	.715996E+07	-.341047E+08	-.203004E+08

TABLE A1 (Continued)

DRAFT

ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NON-DIMENSIONAL	SPEED KTS	Y FORCE KN	K MOMENT KN-M	N MOMENT KN-M
-6.00	-4.00	-.30	5.00	-.292931E+06	.815642E+06	.647335E+05
0.00	-4.00	-.30	5.00	-.283192E+06	.310721E+07	.194201E+07
6.00	-4.00	-.30	5.00	-.274332E+06	.539878E+07	.323669E+07
-6.00	0.00	-.30	5.00	-.150440E+06	.388401E+05	.388401E+07
0.00	0.00	-.30	5.00	-.141591E+06	.233041E+07	.517868E+07
6.00	0.00	-.30	5.00	-.132741E+06	.462197E+07	.647335E+07
-6.00	4.00	-.30	5.00	-.884942E+04	-.647335E+06	.712369E+07
0.00	4.00	-.30	5.00	0.	.155360E+07	.941536E+07
6.00	4.00	-.30	5.00	.884942E+04	.384517E+07	.971003E+07
-6.00	-4.00	0.00	5.00	-.150440E+06	-.151476E+07	-.453135E+07
0.00	-4.00	0.00	5.00	-.141591E+06	.776802E+06	-.323669E+07
6.00	-4.00	0.00	5.00	-.132741E+06	.306837E+07	-.194201E+07
-6.00	0.00	0.00	5.00	-.884942E+04	-.229157E+07	-.129467E+07
0.00	0.00	0.00	5.00	0.	0.	0.
6.00	0.00	0.00	5.00	.884942E+04	.229157E+07	.129467E+07
-6.00	4.00	0.00	5.00	.132741E+06	-.306837E+07	.194201E+07
0.00	4.00	0.00	5.00	.141591E+06	-.776802E+06	.323669E+07
6.00	4.00	0.00	5.00	.150440E+06	.151476E+07	.453135E+07
-6.00	-4.00	.30	5.00	-.884942E+04	-.384517E+07	-.971003E+07
0.00	-4.00	.30	5.00	0.	-.155360E+07	-.941536E+07
6.00	-4.00	.30	5.00	.884942E+04	.647335E+06	-.712369E+07
-6.00	0.00	.30	5.00	.132741E+06	-.462197E+07	-.647335E+07
0.00	0.00	.30	5.00	.141591E+06	-.233041E+07	-.517868E+07
6.00	0.00	.30	5.00	.150440E+06	-.388401E+05	-.388401E+07
-6.00	4.00	.30	5.00	.274332E+06	-.539878E+07	-.323669E+07
0.00	4.00	.30	5.00	.283192E+06	-.310721E+07	-.194201E+07
6.00	4.00	.30	5.00	.292931E+06	-.815642E+06	-.647335E+05
-6.00	-4.00	-.30	10.00	-.573443E+06	.621442E+07	.517368E+06
0.00	-4.00	-.30	10.00	-.566363E+06	.776802E+07	.310721E+07
6.00	-4.00	-.30	10.00	-.553294E+07	.932163E+07	.569655E+07
-6.00	0.00	-.30	10.00	-.637158E+06	.362508E+07	.129467E+08
0.00	0.00	-.30	10.00	-.566363E+06	.517868E+07	.155360E+08
6.00	0.00	-.30	10.00	-.495568E+06	.673229E+07	.181254E+08
-6.00	4.00	-.30	10.00	.446011E+07	.103574E+07	.253755E+08
0.00	4.00	-.30	10.00	.453090E+07	.258934E+07	.279649E+08
6.00	4.00	-.30	10.00	.460170E+07	.414295E+07	.305542E+08
-6.00	-4.00	0.00	10.00	-.516806E+07	.103574E+07	-.150182E+08
0.00	-4.00	0.00	10.00	-.509727E+07	.258934E+07	-.124288E+08
6.00	-4.00	0.00	10.00	-.502647E+07	.414295E+07	-.983950E+07
-6.00	0.00	0.00	10.00	-.707954E+05	-.155360E+07	-.258934E+07
0.00	0.00	0.00	10.00	0.	0.	0.
6.00	0.00	0.00	10.00	.707954E+05	.155360E+07	.258934E+07
-6.00	4.00	0.00	10.00	.502647E+07	-.414295E+07	.983950E+07
0.00	4.00	0.00	10.00	.509727E+07	-.258934E+07	.124288E+08
6.00	4.00	0.00	10.00	.516806E+07	-.103574E+07	.150182E+08
-6.00	-4.00	.30	10.00	-.460170E+07	-.414295E+07	-.305542E+08

TABLE A2 Hydrodynamic Hull Data for Strut Rudder Configuration at Deep Draft

DRAFT

ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NON-DIMENSIONAL	SPEED KTS	Y FORCE NT	K MOMENT NT-M	N MOMENT NT-M
0.00	-4.00	.30	10.00	-.453099E+07	-.254934E+07	-.279649E+08
6.00	-4.00	.30	10.00	-.446011E+07	-.103574E+07	-.253755E+08
-6.00	0.00	.30	10.00	.495666E+06	-.673229E+07	-.131254E+08
0.00	0.00	.30	10.00	.566363E+06	-.517968E+07	-.155369E+08
6.00	0.00	.30	10.00	.637158E+06	-.342609E+07	-.129467E+08
-6.00	4.00	.30	10.00	.559284E+07	-.932163E+07	-.569655E+07
0.00	4.00	.30	10.00	.566363E+07	-.776902E+07	-.310721E+07
6.00	4.00	.30	10.00	.573443E+07	-.621442E+07	-.517969E+06
-6.00	-4.00	-.30	15.00	-.238934E+07	.179441E+08	0.
0.00	-4.00	-.30	15.00	-.238934E+07	.199250E+08	.932163E+07
6.00	-4.00	-.30	15.00	-.238934E+07	.219058E+08	.186433E+08
-6.00	0.00	-.30	15.00	-.955738E+06	.104968E+08	.256345E+08
0.00	0.00	-.30	15.00	-.955738E+06	.124677E+08	.349561E+08
6.00	0.00	-.30	15.00	-.955738E+06	.144485E+08	.440777E+08
-6.00	4.00	-.30	15.00	.477969E+06	.302953E+07	.510699E+08
0.00	4.00	-.30	15.00	.477969E+06	.501037E+07	.605906E+08
6.00	4.00	-.30	15.00	.477969E+06	.699122E+07	.699122E+08
-6.00	-4.00	0.00	15.00	-.143761E+07	.547646E+07	-.349561E+08
0.00	-4.00	0.00	15.00	-.143761E+07	.745730E+07	-.256345E+08
6.00	-4.00	0.00	15.00	-.143761E+07	.943815E+07	-.163129E+08
-6.00	0.00	0.00	15.00	0.	-.198085E+07	-.932163E+07
0.00	0.00	0.00	15.00	0.	0.	0.
6.00	0.00	0.00	15.00	0.	.198085E+07	.932163E+07
-6.00	4.00	0.00	15.00	.143761E+07	-.943815E+07	.163129E+08
0.00	4.00	0.00	15.00	.143761E+07	-.745730E+07	.256345E+08
6.00	4.00	0.00	15.00	.143761E+07	-.547646E+07	.349561E+08
-6.00	-4.00	.30	15.00	-.477969E+06	-.699122E+07	-.699122E+08
0.00	-4.00	.30	15.00	-.477969E+06	-.501037E+07	-.605906E+08
6.00	-4.00	.30	15.00	-.477969E+06	-.302953E+07	-.510699E+08
-6.00	0.00	.30	15.00	.955738E+06	-.144485E+08	-.440777E+08
0.00	0.00	.30	15.00	.955738E+06	-.124677E+08	-.349561E+08
6.00	0.00	.30	15.00	.955738E+06	-.104968E+08	-.256345E+08
-6.00	4.00	.30	15.00	.238934E+07	-.219058E+08	-.186433E+08
0.00	4.00	.30	15.00	.238934E+07	-.199250E+08	-.932163E+07
6.00	4.00	.30	15.00	.238934E+07	-.179441E+08	0.
-6.00	-4.00	-.30	20.00	-.509727E+07	.337659E+08	.290006E+08
0.00	-4.00	-.30	20.00	-.509727E+07	.379289E+08	.455724E+08
6.00	-4.00	-.30	20.00	-.509727E+07	.420919E+08	.621442E+08
-6.00	0.00	-.30	20.00	-.339818E+07	.275306E+08	.270012E+08
0.00	0.00	-.30	20.00	-.339818E+07	.316935E+08	.103574E+08
6.00	0.00	-.30	20.00	-.339818E+07	.358565E+08	.120145E+08
-6.00	4.00	-.30	20.00	-.169909E+07	.213362E+08	.161577E+08
0.00	4.00	-.30	20.00	-.169909E+07	.254791E+08	.174147E+08
6.00	4.00	-.30	20.00	-.169909E+07	.296221E+08	.194719E+08
-6.00	-4.00	0.00	20.00	-.169909E+07	.207147E+07	-.311442E+08
0.00	-4.00	0.00	20.00	-.169909E+07	.621442E+07	-.745730E+08

TABLE A2 (Continued)

DRAFT

ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NON-DIMENSIONAL	SPEED KTS	Y FORCE NTS	K MOMENT NT-M	N MOMENT NT-M
6.00	-4.00	0.00	20.00	-.169909E+07	.103574E+08	-.580012E+08
-6.00	0.00	0.00	20.00	0.	-.414295E+07	-.165718E+08
0.00	0.00	0.00	20.00	0.	0.	0.
6.00	0.00	0.00	20.00	0.	.414295E+07	.165718E+08
-6.00	4.00	0.00	20.00	.169909E+07	-.103574E+08	.580012E+08
0.00	4.00	0.00	20.00	.169909E+07	-.621442E+07	.745730E+08
6.00	4.00	0.00	20.00	.169909E+07	-.207147E+07	.911448E+08
-6.00	-4.00	.30	20.00	.169909E+07	-.296221E+08	-.194712E+09
0.00	-4.00	.30	20.00	.169909E+07	-.254791E+08	-.178140E+09
6.00	-4.00	.30	20.00	.169909E+07	-.213362E+08	-.161569E+09
-6.00	0.00	.30	20.00	.339818E+07	-.358365E+08	-.120145E+09
0.00	0.00	.30	20.00	.339818E+07	-.316935E+08	-.103574E+09
6.00	0.00	.30	20.00	.339818E+07	-.275506E+08	-.870019E+08
-6.00	4.00	.30	20.00	.509727E+07	-.420509E+08	-.621442E+08
0.00	4.00	.30	20.00	.509727E+07	-.379080E+08	-.455724E+08
6.00	4.00	.30	20.00	.509727E+07	-.337650E+08	-.290006E+08
-6.00	-4.	-.30	25.00	-.769900E+07	.420768E+08	.332401E+08
0.00	-4.00	-.30	25.00	-.836270E+07	.420768E+08	.554602E+08
6.00	-4.00	-.30	25.00	-.902641E+07	.420768E+08	.776802E+08
-6.00	0.00	-.30	25.00	-.398224E+07	.291301E+08	.135940E+09
0.00	0.00	-.30	25.00	-.331853E+07	.291301E+08	.155360E+09
6.00	0.00	-.30	25.00	-.265483E+07	.291301E+08	.174781E+09
-6.00	4.00	-.30	25.00	-.265483E+06	.161834E+08	.233041E+09
0.00	4.00	-.30	25.00	.398224E+06	.161834E+08	.252461E+09
6.00	4.00	-.30	25.00	.106193E+07	.161834E+08	.271881E+09
-6.00	-4.00	0.00	25.00	-.438046E+07	.129467E+08	-.116520E+09
0.00	-4.00	0.00	25.00	-.371676E+07	.129467E+08	-.971003E+08
6.00	-4.00	0.00	25.00	-.305305E+07	.129467E+08	-.776802E+08
-6.00	0.00	0.00	25.00	-.663707E+06	0.	-.194201E+08
0.00	0.00	0.00	25.00	0.	0.	0.
6.00	0.00	0.00	25.00	.663707E+06	0.	.194201E+08
-6.00	4.00	0.00	25.00	.305305E+07	-.129467E+08	.776802E+08
0.00	4.00	0.00	25.00	.371676E+07	-.129467E+08	.971003E+08
6.00	4.00	0.00	25.00	.438046E+07	-.129467E+08	.116520E+09
-6.00	-4.00	.30	25.00	-.106193E+07	-.161834E+08	-.271881E+09
0.00	-4.00	.30	25.00	-.398224E+06	-.161834E+08	-.252461E+09
6.00	-4.00	.30	25.00	.265483E+06	-.161834E+08	-.233041E+09
-6.00	0.00	.30	25.00	.265483E+07	-.291301E+08	-.174781E+09
0.00	0.00	.30	25.00	.331853E+07	-.291301E+08	-.155360E+09
6.00	0.00	.30	25.00	.398224E+07	-.291301E+08	-.135940E+09
-6.00	4.00	.30	25.00	.902641E+07	-.420768E+08	-.776802E+08
0.00	4.00	.30	25.00	.836270E+07	-.420768E+08	-.554602E+08
6.00	4.00	.30	25.00	.769900E+07	-.420768E+08	-.332401E+08
-6.00	-4.00	-.30	28.00	-.113782E+08	.438489E+08	.324907E+08
0.00	-4.00	-.30	28.00	-.105457E+08	.438489E+08	.568412E+08
6.00	-4.00	-.30	28.00	-.971313E+07	.438489E+08	.812017E+08

TABLE A2 (Continued)

DRAFT

ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NON-DIMENSIONAL	SPEED KTS	Y FORCE NTS	K MOMENT NT-M	N MOMENT NT-M
-4.00	0.00	-.30	28.00	-.638291E+07	.251725E+08	.146163E+09
0.00	0.00	-.30	28.00	-.555036E+07	.251725E+08	.170524E+09
4.00	0.00	-.30	28.00	-.471780E+07	.251725E+08	.194884E+09
-4.00	4.00	-.30	28.00	-.138759E+07	.812017E+07	.258946E+09
0.00	4.00	-.30	28.00	-.555036E+06	.812017E+07	.284206E+09
4.00	4.00	-.30	28.00	.277519E+06	.812017E+07	.309567E+09
-4.00	-4.00	0.00	28.00	-.582788E+07	.170524E+08	-.138043E+09
0.00	-4.00	0.00	28.00	-.499532E+07	.170524E+08	-.113682E+09
4.00	-4.00	0.00	28.00	-.416277E+07	.170524E+08	-.893213E+08
-4.00	0.00	0.00	28.00	-.832554E+06	0.	-.243605E+08
0.00	0.00	0.00	28.00	0.	0.	0.
4.00	0.00	0.00	28.00	.832554E+06	0.	.243605E+08
-4.00	4.00	0.00	28.00	.416277E+07	-.170524E+08	.893213E+08
0.00	4.00	0.00	28.00	.499532E+07	-.170524E+08	.113682E+09
4.00	4.00	0.00	28.00	.582788E+07	-.170524E+08	.138043E+09
-4.00	-4.00	.30	28.00	-.277519E+06	-.812017E+07	-.309567E+09
0.00	-4.00	.30	28.00	.555036E+06	-.812017E+07	-.284206E+09
4.00	-4.00	.30	28.00	.138759E+07	-.812017E+07	-.258946E+09
-4.00	0.00	.30	28.00	.471780E+07	-.251725E+08	-.194884E+09
0.00	0.00	.30	28.00	.555036E+07	-.251725E+08	-.170524E+09
4.00	0.00	.30	28.00	.638291E+07	-.251725E+08	-.146163E+09
-4.00	4.00	.30	28.00	.971317E+07	-.438489E+08	-.810017E+08
0.00	4.00	.30	28.00	.105457E+08	-.438489E+08	-.569412E+08
4.00	4.00	.30	28.00	.113782E+08	-.438489E+08	-.324807E+08

TABLE A2 (Continued)

DRAFT

RUDDER ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NON-DIMENSIONAL	SPEED KTS	Y FORCE NT	K MOMENT NT-M	N MOMENT NT-M
-4.00	-4.00	-.30	5.00	-.296721E+06	.304249E+07	.233041E+07
0.00	-4.00	-.30	5.00	-.296721E+06	.304249E+07	.233041E+07
4.00	-4.00	-.30	5.00	-.296721E+06	.304249E+07	.233041E+07
-4.00	0.00	-.30	5.00	-.176988E+06	.245987E+07	.517968E+07
0.00	0.00	-.30	5.00	-.176988E+06	.245987E+07	.517968E+07
4.00	0.00	-.30	5.00	-.176988E+06	.245987E+07	.517968E+07
-4.00	4.00	-.30	5.00	-.672556E+05	.197727E+07	.800696E+07
0.00	4.00	-.30	5.00	-.672556E+05	.197727E+07	.800696E+07
4.00	4.00	-.30	5.00	-.672556E+05	.197727E+07	.800696E+07
-4.00	-4.00	0.00	5.00	-.109733E+06	.582602E+06	-.284929E+07
0.00	-4.00	0.00	5.00	-.109733E+06	.582602E+06	-.284929E+07
4.00	-4.00	0.00	5.00	-.109733E+06	.582602E+06	-.284929E+07
-4.00	0.00	0.00	5.00	0.	0.	0.
0.00	0.00	0.00	5.00	0.	0.	0.
4.00	0.00	0.00	5.00	0.	0.	0.
-4.00	4.00	0.00	5.00	.109733E+06	-.582602E+06	.284929E+07
0.00	4.00	0.00	5.00	.109733E+06	-.582602E+06	.284929E+07
4.00	4.00	0.00	5.00	.109733E+06	-.582602E+06	.284929E+07
-4.00	-4.00	.30	5.00	.672556E+05	-.197727E+07	-.800696E+07
0.00	-4.00	.30	5.00	.672556E+05	-.197727E+07	-.800696E+07
4.00	-4.00	.30	5.00	.672556E+05	-.197727E+07	-.800696E+07
-4.00	0.00	.30	5.00	.176988E+06	-.245987E+07	-.517968E+07
0.00	0.00	.30	5.00	.176988E+06	-.245987E+07	-.517968E+07
4.00	0.00	.30	5.00	.176988E+06	-.245987E+07	-.517968E+07
-4.00	4.00	.30	5.00	.296721E+06	-.304249E+07	-.233041E+07
0.00	4.00	.30	5.00	.296721E+06	-.304249E+07	-.233041E+07
4.00	4.00	.30	5.00	.296721E+06	-.304249E+07	-.233041E+07
-4.00	-4.00	-.30	10.00	-.109733E+07	.776902E+07	.517968E+07
0.00	-4.00	-.30	10.00	-.109733E+07	.776902E+07	.517968E+07
4.00	-4.00	-.30	10.00	-.109733E+07	.776902E+07	.517968E+07
-4.00	0.00	-.30	10.00	-.672556E+06	.569655E+07	.155360E+08
0.00	0.00	-.30	10.00	-.672556E+06	.569655E+07	.155360E+08
4.00	0.00	-.30	10.00	-.672556E+06	.569655E+07	.155360E+08
-4.00	4.00	-.30	10.00	-.247784E+06	.362508E+07	.258934E+08
0.00	4.00	-.30	10.00	-.247784E+06	.362508E+07	.258934E+08
4.00	4.00	-.30	10.00	-.247784E+06	.362508E+07	.258934E+08
-4.00	-4.00	0.00	10.00	-.424772E+06	.207147E+07	-.103574E+08
0.00	-4.00	0.00	10.00	-.424772E+06	.207147E+07	-.103574E+08
4.00	-4.00	0.00	10.00	-.424772E+06	.207147E+07	-.103574E+08
-4.00	0.00	0.00	10.00	0.	0.	0.
0.00	0.00	0.00	10.00	0.	0.	0.
4.00	0.00	0.00	10.00	0.	0.	0.
-4.00	4.00	0.00	10.00	.424772E+06	-.207147E+07	.103574E+08
0.00	4.00	0.00	10.00	.424772E+06	-.207147E+07	.103574E+08
4.00	4.00	0.00	10.00	.424772E+06	-.207147E+07	.103574E+08
-4.00	-4.00	.30	10.00	.247784E+06	-.362508E+07	-.258934E+08

TABLE A3 Hydrodynamic Hull Data for Spade Rudder Configuration at Design Draft

DRAFT

HEEL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NONDIMENSIONAL	SPEED KTS	Y FORCE LT	K MOMENT FT-LT	N MOMENT FT-LT
[illegible]	-4.	.30	10.00	.247724E+06	-.362592E+07	-.255234E+08
[illegible]	-4.00	.30	10.00	.247724E+06	-.362592E+07	-.254234E+08
[illegible]	[illegible]	.30	10.00	.670556E+06	-.560455E+07	-.155760E+08
[illegible]	[illegible]	.30	10.00	.670556E+06	-.560455E+07	-.155760E+08
[illegible]	[illegible]	.30	10.00	.670556E+06	-.560455E+07	-.155760E+08
[illegible]	4.00	.30	10.00	.109733E+07	-.776499E+07	-.717869E+07
[illegible]	4.00	.30	10.00	.109733E+07	-.776499E+07	-.717869E+07
[illegible]	4.00	.30	10.00	.109733E+07	-.776499E+07	-.517466E+07
[illegible]	-4.00	-.30	15.00	-.213448E+07	.167729E+08	-.237341E+07
[illegible]	-4.00	-.30	15.00	-.213448E+07	.167729E+08	.173304E+08
[illegible]	-4.00	-.30	15.00	-.213448E+07	.167729E+08	.330957E+08
[illegible]	0.00	-.30	15.00	-.111503E+07	.116520E+09	.233241E+08
[illegible]	[illegible]	-.30	15.00	-.111503E+07	.116520E+09	.706163E+08
[illegible]	[illegible]	-.30	15.00	-.111503E+07	.116520E+09	[illegible]
[illegible]	4.00	-.30	15.00	-.955738E+05	.652514E+07	.499785E+08
[illegible]	4.00	-.30	15.00	-.955738E+05	.652514E+07	.652514E+08
[illegible]	4.00	-.30	15.00	-.955738E+05	.652514E+07	.315649E+08
-4.00	-4.00	0.00	15.00	-.101945E+07	.512699E+07	-.419473E+08
[illegible]	-4.00	0.00	15.00	-.101945E+07	.512699E+07	[illegible]
[illegible]	-4.00	0.00	15.00	-.101945E+07	.512699E+07	-.237163E+07
-4.00	0.00	0.00	15.00	0.	0.	-.167129E+08
[illegible]	[illegible]	0.00	15.00	0.	0.	0.
[illegible]	[illegible]	0.00	15.00	0.	0.	.167129E+08
[illegible]	4.00	0.00	15.00	.101945E+07	-.512699E+07	.237163E+07
[illegible]	4.00	0.00	15.00	.101945E+07	-.512699E+07	[illegible]
[illegible]	4.00	0.00	15.00	.101945E+07	-.512699E+07	.419473E+08
[illegible]	-4.00	.30	15.00	.955738E+05	-.652514E+07	[illegible]
[illegible]	-4.00	.30	15.00	.955738E+05	-.652514E+07	-.652514E+08
[illegible]	-4.00	.30	15.00	.955738E+05	-.652514E+07	-.499785E+08
[illegible]	[illegible]	.30	15.00	.111503E+07	-.116520E+09	[illegible]
[illegible]	[illegible]	.30	15.00	.111503E+07	-.116520E+09	-.396149E+08
[illegible]	0.00	.30	15.00	.111503E+06	-.116520E+09	-.233241E+08
[illegible]	4.00	.30	15.00	.213448E+07	-.167729E+08	-.330957E+08
[illegible]	4.00	.30	15.00	.213448E+07	-.167729E+08	-.173304E+08
[illegible]	4.00	.30	15.00	.213448E+07	-.167729E+08	.237341E+07
[illegible]	-4.00	-.30	20.00	-.379463E+07	.314964E+08	.227562E+08
[illegible]	-4.00	-.30	20.00	-.379463E+07	.356203E+08	.331436E+08
[illegible]	-4.00	-.30	20.00	-.379463E+07	.327723E+08	.435033E+08
[illegible]	[illegible]	-.30	20.00	-.254863E+07	.248577E+08	.725017E+08
[illegible]	0.00	-.30	20.00	-.254863E+07	.290006E+08	[illegible]
[illegible]	0.00	-.30	20.00	-.254863E+07	.331476E+08	.330163E+08
[illegible]	4.00	-.30	20.00	-.170263E+07	.182290E+08	.122217E+08
[illegible]	4.00	-.30	20.00	-.170263E+07	.223712E+08	.130574E+08
[illegible]	4.00	-.30	20.00	-.170263E+07	.265149E+08	.133332E+08
[illegible]	-4.00	0.00	20.00	-.124600E+07	.249577E+07	-.600707E+08
[illegible]	-4.00	0.00	20.00	-.124600E+07	.652871E+07	-.437153E+08

DRAFT

TABLE A3 (Continued)

[illegible]	[illegible]	[illegible] NONDIMENSIONAL	[illegible]	Y FORCE NT	K MOMENT NT-M	N MOMENT NT-M
0.00	-4.00	0.00	20.00	-.124600E+07	.107717E+08	-.397583E+08
-5.00	0.00	0.00	20.00	0.	-.414035E+07	-.103574E+08
.00	0.00	0.00	20.00	0.	0.	0.
5.00	0.00	0.00	20.00	0.	.414035E+07	.103574E+08
-5.00	4.00	0.00	20.00	.124600E+07	-.107717E+08	.397583E+08
0.00	4.00	0.00	20.00	.124600E+07	-.662971E+07	.437153E+08
5.00	4.00	0.00	20.00	.124600E+07	-.249577E+07	.607727E+08
-5.00	-4.00	.30	20.00	.130263E+07	-.265149E+08	-.140332E+08
0.00	-4.00	.30	20.00	.130263E+07	-.223719E+08	-.133274E+08
5.00	-4.00	.30	20.00	.130263E+07	-.182205E+08	-.122217E+08
-5.00	0.00	.30	20.00	.254963E+07	-.371436E+08	-.332163E+08
.00	0.00	.30	20.00	.254963E+07	-.290006E+08	-.502509E+08
5.00	0.00	.30	20.00	.254963E+07	-.248577E+08	-.725015E+08
-5.00	4.00	.30	20.00	.379463E+07	-.397723E+08	-.435009E+08
.00	4.00	.30	20.00	.379463E+07	-.356223E+08	-.331434E+08
5.00	4.00	.30	20.00	.379463E+07	-.314364E+08	-.227562E+08
-5.00	-4.00	-.30	25.00	-.519450E+07	.352798E+08	.151874E+08
0.00	-4.00	-.30	25.00	-.575012E+07	.395164E+08	.425501E+08
5.00	-4.00	-.30	25.00	-.530765E+07	.417531E+08	.809149E+08
-5.00	0.00	-.30	25.00	-.398024E+07	.275117E+08	.113294E+08
.00	0.00	-.30	25.00	-.353077E+07	.307484E+08	.145505E+08
5.00	0.00	-.30	25.00	-.309730E+07	.339951E+08	.177017E+08
-5.00	4.00	-.30	25.00	-.176389E+07	.197437E+08	.210394E+08
0.00	4.00	-.30	25.00	-.132741E+07	.229094E+08	.242751E+08
5.00	4.00	-.30	25.00	-.884042E+06	.262171E+08	.275117E+08
-5.00	-4.00	0.00	25.00	-.265483E+07	.457135E+07	-.647335E+08
0.00	-4.00	0.00	25.00	-.221036E+07	.776902E+07	-.371033E+08
5.00	-4.00	0.00	25.00	-.176988E+07	.110047E+08	-.129467E+08
-5.00	0.00	0.00	25.00	-.442471E+06	-.323669E+07	-.327660E+08
.00	0.00	0.00	25.00	0.	0.	0.
5.00	0.00	0.00	25.00	.442471E+06	.323662E+07	.327666E+08
-5.00	4.00	0.00	25.00	.176388E+07	-.110047E+08	.129467E+08
0.00	4.00	0.00	25.00	.221036E+07	-.776902E+07	.371033E+08
5.00	4.00	0.00	25.00	.265483E+07	-.457135E+07	.647335E+08
-5.00	-4.00	.30	25.00	.884042E+06	-.262171E+08	-.275117E+08
0.00	-4.00	.30	25.00	.132741E+07	-.229094E+08	-.242751E+08
5.00	-4.00	.30	25.00	.176388E+07	-.197437E+08	-.210394E+08
-5.00	0.00	.30	25.00	.309730E+07	-.339951E+08	-.177017E+08
.00	0.00	.30	25.00	.353077E+07	-.307484E+08	-.145505E+08
5.00	0.00	.30	25.00	.398024E+07	-.275117E+08	-.113294E+08
-5.00	4.00	.30	25.00	.530765E+07	-.417571E+08	-.809169E+08
0.00	4.00	.30	25.00	.575012E+07	-.395164E+08	-.425501E+08
5.00	4.00	.30	25.00	.619460E+07	-.352798E+08	-.151934E+08
-5.00	-4.00	-.30	28.00	-.577144E+07	.406009E+08	.365409E+08
.00	-4.00	-.30	28.00	-.566043E+07	.446610E+08	.406009E+08
[illegible]	-4.00	-.30	28.00	-.554942E+07	.487210E+08	.446610E+08

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TABLE A3 (Continued)

ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NON-DIMENSIONAL	SPEED KTS	Y FORCE [illegible]	K MOMENT MT-M	N MOMENT MT-M
[illegible]	[illegible]	-.30	28.00	-.344122E+07	.324807E+08	.159743E+08
[illegible]	[illegible]	-.30	28.00	-.333021E+07	.365409E+08	.162403E+08
[illegible]	[illegible]	-.30	28.00	-.321921E+07	.406009E+08	.166464E+08
-6.00	4.00	-.30	28.00	-.111007E+06	.243605E+08	.280146E+08
[illegible]	4.00	-.30	28.00	0.	.284206E+08	.284206E+08
[illegible]	4.00	-.30	28.00	.111007E+06	.324807E+08	.284266E+08
[illegible]	-4.00	0.00	28.00	-.344122E+07	.406009E+07	-.125863E+08
[illegible]	-4.00	0.00	28.00	-.333021E+07	.812017E+07	-.121803E+08
[illegible]	-4.00	0.00	28.00	-.321921E+07	.121803E+08	-.117743E+08
-6.00	[illegible]	0.00	28.00	-.111007E+06	-.406009E+07	-.406009E+07
[illegible]	[illegible]	0.00	28.00	0.	0.	0.
[illegible]	.00	0.00	28.00	.111007E+06	.406009E+07	.406009E+07
[illegible]	[illegible]	0.00	28.00	.321921E+07	-.121803E+08	.117743E+08
[illegible]	4.00	0.00	28.00	.333021E+07	-.812017E+07	.121803E+08
[illegible]	4.00	0.00	28.00	.344122E+07	-.406009E+07	.125863E+08
[illegible]	-4.00	.30	28.00	.111007E+06	-.324807E+08	-.284266E+08
[illegible]	-4.00	.30	28.00	0.	-.284206E+08	-.284206E+08
[illegible]	-4.00	.30	28.00	-.111007E+06	-.243605E+08	-.280146E+08
[illegible]	[illegible]	.30	28.00	.321921E+07	-.406009E+08	-.166464E+08
[illegible]	[illegible]	.30	28.00	.333021E+07	-.365409E+08	-.162403E+08
[illegible]	[illegible]	.30	28.00	.344122E+07	-.324807E+08	-.159743E+08
[illegible]	4.00	.30	28.00	.654942E+07	-.487210E+08	-.446619E+08
[illegible]	4.00	.30	28.00	.666043E+07	-.446610E+08	-.406003E+08
[illegible]	4.00	.30	28.00	.677144E+07	-.406009E+08	-.365409E+08

TABLE A3 (Continued)

DRAFT

ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE (NONDIMENSIONAL)	SPEED KTS	Y FORCE, LTS	K MOMENT LT-M	N MOMENT LT-M
-6.00	-4.00	-.30	5.00	-.334508E+06	.233041E+07	.310721E+07
0.00	-4.00	-.30	5.00	-.352207E+06	.245387E+07	.440188E+07
6.00	-4.00	-.30	5.00	-.369806E+06	.259934E+07	.562655E+07
-6.00	0.00	-.30	5.00	-.185838E+06	.245997E+07	.517868E+07
0.00	0.00	-.30	5.00	-.203537E+06	.258934E+07	.647335E+07
6.00	0.00	-.30	5.00	-.221036E+06	.271881E+07	.776802E+07
-6.00	4.00	-.30	5.00	-.371676E+05	.142414E+07	.725015E+07
0.00	4.00	-.30	5.00	-.548664E+05	.155360E+07	.854493E+07
6.00	4.00	-.30	5.00	-.725653E+05	.168307E+07	.983970E+07
-6.00	-4.00	0.00	5.00	-.130971E+06	.906269E+06	-.336614E+07
0.00	-4.00	0.00	5.00	-.148670E+06	.103574E+07	-.207147E+07
6.00	-4.00	0.00	5.00	-.166369E+06	.116520E+07	-.776802E+06
-6.00	0.00	0.00	5.00	.176988E+05	-.129467E+06	-.129467E+07
0.00	0.00	0.00	5.00	0.	0.	0.
6.00	0.00	0.00	5.00	-.176988E+05	.129467E+06	.129467E+07
-6.00	4.00	0.00	5.00	.166369E+06	-.116520E+07	.776802E+06
0.00	4.00	0.00	5.00	.148670E+06	-.103574E+07	.207147E+07
6.00	4.00	0.00	5.00	.130971E+06	-.906269E+06	.336614E+07
-6.00	-4.00	.30	5.00	.725653E+05	-.168307E+07	-.983970E+07
0.00	-4.00	.30	5.00	.548664E+05	-.155360E+07	-.854493E+07
6.00	-4.00	.30	5.00	.371676E+05	-.142414E+07	-.725015E+07
-6.00	0.00	.30	5.00	.221036E+06	-.271881E+07	-.776802E+07
0.00	0.00	.30	5.00	.203537E+06	-.258934E+07	-.647335E+07
6.00	0.00	.30	5.00	.185838E+06	-.245997E+07	-.517868E+07
-6.00	4.00	.30	5.00	.369806E+06	-.259934E+07	-.562655E+07
0.00	4.00	.30	5.00	.352207E+06	-.245387E+07	-.440188E+07
6.00	4.00	.30	5.00	.334508E+06	-.233041E+07	-.310721E+07
-6.00	-4.00	-.30	10.00	-.127430E+07	.100994E+08	.673229E+07
0.00	-4.00	-.30	10.00	-.134511E+07	.106163E+08	.112111E+08
6.00	-4.00	-.30	10.00	-.141591E+07	.111342E+08	.170897E+08
-6.00	0.00	-.30	10.00	-.707954E+06	.621442E+07	.145003E+08
0.00	0.00	-.30	10.00	-.778749E+06	.673229E+07	.196790E+08
6.00	0.00	-.30	10.00	-.849545E+06	.725015E+07	.248577E+08
-6.00	4.00	-.30	10.00	-.141591E+06	.233041E+07	.222683E+08
0.00	4.00	-.30	10.00	-.212386E+06	.284828E+07	.274470E+08
6.00	4.00	-.30	10.00	-.283182E+06	.336614E+07	.326257E+08
-6.00	-4.00	0.00	10.00	-.495568E+06	.336614E+07	-.129467E+08
0.00	-4.00	0.00	10.00	-.566363E+07	.388401E+07	-.776802E+07
6.00	-4.00	0.00	10.00	-.637158E+06	.440138E+07	-.258934E+07
-6.00	0.00	0.00	10.00	.707954E+05	-.517868E+06	-.517868E+07
0.00	0.00	0.00	10.00	0.	0.	0.
6.00	0.00	0.00	10.00	-.707954E+05	.517868E+06	.517868E+07
-6.00	4.00	0.00	10.00	.637159E+06	-.440188E+07	.258934E+07
0.00	4.00	0.00	10.00	.566363E+06	-.388401E+07	.776802E+07
6.00	4.00	0.00	10.00	.495568E+06	-.336614E+07	.129467E+08
-6.00	-4.00	.30	10.00	.283182E+06	-.336614E+07	-.326257E+08

TABLE A4 Hydrodynamic Hull Data for Spade Rudder Configuration at Deep Draft

DRAFT

ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE, NON-DIMENSIONAL	SPEED KTS	Y FORCE NT	K MOMENT NT-M	N MOMENT NT-M
0.00	-4.00	.30	10.00	.212196E+06	-.244929E+07	-.274470E+08
4.00	-4.00	.30	10.00	.141591E+06	-.233241E+07	-.202683E+08
-4.00	0.00	.30	10.00	.549545E+06	-.725015E+07	-.242577E+08
0.00	0.00	.30	10.00	.776749E+06	-.673029E+07	-.196790E+08
4.00	0.00	.30	10.00	.707054E+06	-.621442E+07	-.145003E+08
-4.00	4.00	.30	10.00	.141591E+07	-.111342E+08	-.170897E+08
0.00	4.00	.30	10.00	.134511E+07	-.106163E+08	-.119110E+08
4.00	4.00	.30	10.00	.127432E+07	-.100984E+08	-.673229E+07
-4.00	-4.00	-.30	15.00	-.261235E+07	.199085E+08	.815642E+07
0.00	-4.00	-.30	15.00	-.277164E+07	.209737E+08	.199095E+08
4.00	-4.00	-.30	15.00	-.293093E+07	.221389E+08	.314605E+08
-4.00	0.00	-.30	15.00	-.127432E+07	.116529E+08	.314605E+08
0.00	0.00	-.30	15.00	-.143361E+07	.128172E+08	.431125E+08
4.00	0.00	-.30	15.00	-.159290E+07	.139824E+08	.547646E+08
-4.00	4.00	-.30	15.00	.637159E+05	.349561E+07	.547646E+08
0.00	4.00	-.30	15.00	-.955738E+05	.466081E+07	.664166E+08
4.00	4.00	-.30	15.00	-.254863E+06	.582602E+07	.780686E+08
-4.00	-4.00	0.00	15.00	-.117274E+07	.699122E+07	-.349561E+08
0.00	-4.00	0.00	15.00	-.133203E+07	.815642E+07	-.233041E+08
4.00	-4.00	0.00	15.00	-.149732E+07	.932163E+07	-.116520E+08
-4.00	0.00	0.00	15.00	.159290E+06	-.116520E+07	-.116520E+08
0.00	0.00	0.00	15.00	0.	0.	0.
4.00	0.00	0.00	15.00	-.159290E+06	.116520E+07	.116520E+08
-4.00	4.00	0.00	15.00	.149732E+07	-.932163E+07	.116520E+08
0.00	4.00	0.00	15.00	.133203E+07	-.815642E+07	.233041E+08
4.00	4.00	0.00	15.00	.117274E+07	-.699122E+07	.349561E+08
-4.00	-4.00	.30	15.00	.254863E+06	-.582602E+07	-.780686E+08
0.00	-4.00	.30	15.00	.955738E+05	-.466081E+07	-.664166E+08
4.00	-4.00	.30	15.00	-.637159E+05	-.349561E+07	-.547646E+08
-4.00	0.00	.30	15.00	.159290E+07	-.139824E+08	-.547646E+08
0.00	0.00	.30	15.00	.143361E+07	-.128172E+08	-.431125E+08
4.00	0.00	.30	15.00	.127432E+07	-.116529E+08	-.314605E+08
-4.00	4.00	.30	15.00	.293093E+07	-.221389E+08	-.314605E+08
0.00	4.00	.30	15.00	.277164E+07	-.209737E+08	-.199095E+08
4.00	4.00	.30	15.00	.261235E+07	-.199085E+08	-.815642E+07
-4.00	-4.00	-.30	20.00	-.504063E+07	.352150E+08	.145003E+08
0.00	-4.00	-.30	20.00	-.532381E+07	.372865E+08	.352150E+08
4.00	-4.00	-.30	20.00	-.560699E+07	.393580E+08	.559228E+08
-4.00	0.00	-.30	20.00	-.339619E+07	.269291E+08	.766445E+08
0.00	0.00	-.30	20.00	-.368136E+07	.290006E+08	.973592E+08
4.00	0.00	-.30	20.00	-.396454E+07	.310721E+08	.118074E+09
-4.00	4.00	-.30	20.00	-.175573E+07	.186433E+08	.132789E+09
0.00	4.00	-.30	20.00	-.203891E+07	.207147E+08	.153503E+09
4.00	4.00	-.30	20.00	-.232209E+07	.227862E+08	.180218E+09
-4.00	-4.00	0.00	20.00	-.135527E+07	.621442E+07	-.908589E+08
0.00	-4.00	0.00	20.00	-.164245E+07	.823589E+07	-.621442E+08

TABLE A4 (Continued)

DRAFT

ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE (NON-DIMENSIONAL)	SPEED KTS	Y FORCE MTS	K MOMENT MT-M	N MOMENT MT-M
6.00	-4.00	0.00	20.00	-.192563E+07	.103574E+08	-.414295E+08
-6.00	0.00	0.00	20.00	.283132E+06	-.207147E+07	-.207147E+08
0.00	0.00	0.00	20.00	0.	0.	0.
6.00	0.00	0.00	20.00	-.283132E+06	.207147E+07	.207147E+08
-6.00	4.00	0.00	20.00	.192563E+07	-.103574E+08	.414295E+08
0.00	4.00	0.00	20.00	.164245E+07	-.828589E+07	.621442E+08
6.00	4.00	0.00	20.00	.135927E+07	-.621442E+07	.828589E+08
-6.00	-4.00	.30	20.00	.232209E+07	-.227862E+08	-.190219E+09
0.00	-4.00	.30	20.00	.203891E+07	-.207147E+08	-.159537E+09
6.00	-4.00	.30	20.00	.175573E+07	-.186433E+08	-.138769E+09
-6.00	0.00	.30	20.00	.396454E+07	-.310721E+08	-.110074E+09
0.00	0.00	.30	20.00	.368136E+07	-.290006E+08	-.377592E+08
6.00	0.00	.30	20.00	.339818E+07	-.269291E+08	-.766445E+08
-6.00	4.00	.30	20.00	.560609E+07	-.393588E+08	-.550293E+08
0.00	4.00	.30	20.00	.532381E+07	-.372865E+08	-.352150E+08
6.00	4.00	.30	20.00	.504063E+07	-.352150E+08	-.145003E+08
-6.00	-4.00	-.30	25.00	-.716903E+07	.569655E+08	.356034E+09
0.00	-4.00	-.30	25.00	-.672556E+07	.634389E+08	.679702E+09
6.00	-4.00	-.30	25.00	-.628309E+07	.699122E+08	.100337E+09
-6.00	0.00	-.30	25.00	-.442471E+07	.453135E+08	.152124E+09
0.00	0.00	-.30	25.00	-.398224E+07	.517869E+08	.184491E+09
6.00	0.00	-.30	25.00	-.353977E+07	.582602E+08	.216857E+09
-6.00	4.00	-.30	25.00	-.168139E+07	.336614E+08	.269644E+09
0.00	4.00	-.30	25.00	-.123992E+07	.401348E+08	.302011E+09
6.00	4.00	-.30	25.00	-.796449E+06	.466081E+08	.333379E+09
-6.00	-4.00	0.00	25.00	-.318579E+07	.517869E+07	-.146827E+09
0.00	-4.00	0.00	25.00	-.274332E+07	.116520E+09	-.116520E+09
6.00	-4.00	0.00	25.00	-.230085E+07	.181254E+09	-.841536E+08
-6.00	0.00	0.00	25.00	-.442471E+06	-.647335E+07	-.323668E+08
0.00	0.00	0.00	25.00	0.	0.	0.
6.00	0.00	0.00	25.00	.442471E+06	.647335E+07	.323668E+08
-6.00	4.00	0.00	25.00	.230085E+07	-.181254E+09	.841536E+08
0.00	4.00	0.00	25.00	.274332E+07	-.116520E+09	.116520E+09
6.00	4.00	0.00	25.00	.318579E+07	-.517869E+07	.146387E+09
-6.00	-4.00	.30	25.00	.796449E+06	-.466081E+08	-.333379E+09
0.00	-4.00	.30	25.00	.123992E+07	-.401348E+08	-.302011E+09
6.00	-4.00	.30	25.00	.168139E+07	-.336614E+08	-.269644E+09
-6.00	0.00	.30	25.00	.353977E+07	-.582602E+08	-.216857E+09
0.00	0.00	.30	25.00	.398224E+07	-.517869E+08	-.184491E+09
6.00	0.00	.30	25.00	.442471E+07	-.453135E+08	-.152124E+09
-6.00	4.00	.30	25.00	.628309E+07	-.699122E+08	-.100337E+09
0.00	4.00	.30	25.00	.672556E+07	-.634389E+08	-.679702E+08
6.00	4.00	.30	25.00	.716903E+07	-.569655E+08	-.356034E+08
-6.00	-4.00	-.30	28.00	-.904902E+07	.643614E+08	.457211E+09
0.00	-4.00	-.30	28.00	-.777050E+07	.730816E+08	.554412E+09
6.00	-4.00	-.30	28.00	-.749099E+07	.813017E+08	.649614E+09

TABLE A4 (Continued)

DRAFT

ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NONDIMENSIONAL	SPEED KTS	Y FORCE NT	K MOMENT NT-M	N MOMENT NT-M
-4.00	0.00	-.30	28.00	-.416277E+07	.527411E+08	.104884E+09
0.00	0.00	-.30	28.00	-.388525E+07	.609013E+08	.203094E+09
4.00	0.00	-.30	28.00	-.360773E+07	.690215E+08	.211125E+09
-4.00	4.00	-.30	28.00	-.277513E+06	.406109E+08	.341047E+09
0.00	4.00	-.30	28.00	0.	.487210E+08	.340167E+09
4.00	4.	-.30	28.00	.277519E+06	.568412E+08	.357288E+09
-4.00	-4.00	0.00	28.00	-.416277E+07	.406099E+07	-.154293E+09
0.00	-4.00	0.00	28.00	-.388525E+07	.121803E+08	-.146163E+09
4.00	-4.00	0.00	28.00	-.360773E+07	.203094E+08	-.138043E+09
-4.00	0.00	0.00	28.00	-.277513E+06	-.812017E+07	-.812017E+07
0.00	0.00	0.00	28.00	0.	0.	0.
4.00	0.00	0.00	28.00	.277514E+06	.812017E+07	.812017E+07
-4.00	4.00	0.00	28.00	.360773E+07	-.203094E+08	.138043E+09
0.00	4.00	0.00	28.00	.388525E+07	-.121803E+08	.146163E+09
4.00	4.00	0.00	28.00	.416277E+07	-.406099E+07	.154293E+09
-4.00	-4.00	.30	28.00	-.277518E+06	-.568412E+08	-.357288E+09
0.00	-4.00	.30	28.00	0.	-.487210E+08	-.340167E+09
4.00	-4.00	.30	28.00	.277518E+06	-.406109E+08	-.341047E+09
-4.00	0.00	.30	28.00	.360773E+07	-.690215E+08	-.211125E+09
0.00	0.00	.30	28.00	.388525E+07	-.609013E+08	-.203094E+09
4.00	0.00	.30	28.00	.416277E+07	-.527411E+08	-.104884E+09
-4.00	4.00	.30	28.00	.749298E+07	-.812017E+08	-.649614E+08
0.00	4.00	.30	28.00	.777050E+07	-.730916E+08	-.568412E+08
4.00	4.00	.30	28.00	.804802E+07	-.649614E+08	-.487210E+09

TABLE A4 (Continued)

DRAFT

CASE A

TABLE OF RUDDER X VALUES

RUDDER ANGLE - DEG

SPEED KTS	-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
0.0	0.	0.	0.	0.	0.	0.	0.	0.
5.0	-.1240E+06	-.1010E+06	-.9560E+05	-.3540E+05	.3540E+05	.9560E+05	.1010E+06	.1240E+06
10.0	-.3890E+06	-.3360E+06	-.2830E+06	-.1420E+06	.1420E+06	.2830E+06	.3360E+06	.3890E+06
15.0	-.4780E+06	-.4220E+06	-.3670E+06	-.1590E+06	.1590E+06	.3670E+06	.4220E+06	.4780E+06
20.0	-.5670E+06	-.4960E+06	-.4250E+06	-.2830E+06	.2830E+06	.4250E+06	.4960E+06	.5670E+06
25.0	-.4430E+06	-.3760E+06	-.3100E+06	-.2210E+06	.2210E+06	.3100E+06	.3760E+06	.4430E+06
28.0	-.3890E+06	-.3330E+06	-.2760E+06	-.2210E+06	.2210E+06	.2760E+06	.3330E+06	.3890E+06

TABLE A5 Hydrodynamic Data for Strut Rudder at Design Draft

CASE A

TABLE OF RUDDER Y VALUES

RUDDER ANGLE - DEG

SPEED KTS	-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
0.0	0.	0.	0.	0.	0.	0.	0.	0.
5.0	-.2300E+06	-.2300E+06	-.2300E+06	-.1770E+06	.1770E+06	.2300E+06	.2300E+06	.2300E+06
10.0	-.7080E+06	-.6970E+06	-.6870E+06	-.5310E+06	.5310E+06	.6870E+06	.6970E+06	.7080E+06
15.0	-.1140E+07	-.1080E+07	-.1020E+07	-.7970E+06	.7970E+06	.1020E+07	.1080E+07	.1140E+07
20.0	-.2010E+07	-.1800E+07	-.1590E+07	-.8790E+06	.8790E+06	.1590E+07	.1800E+07	.2010E+07
25.0	-.1630E+07	-.1280E+07	-.9300E+06	-.6200E+06	.6200E+06	.9300E+06	.1280E+07	.1630E+07
28.0	-.9990E+06	-.9440E+06	-.8890E+06	-.6110E+06	.6110E+06	.8890E+06	.9440E+06	.9990E+06

TABLE A5 (Continued)

CASE A

TABLE OF RUDDER K VALUES

RUDDER ANGLE - DEG

		-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
	0.0	0.	0.	0.	0.	0.	0.	0.	0.
	5.0	.6480E+06	.6090E+06	.5700E+06	.4540E+06	-.4540E+06	-.5700E+06	-.6090E+06	-.6480E+06
SPEED	10.0	.3110E+07	.2800E+07	.2590E+07	.2070E+07	-.2070E+07	-.2590E+07	-.2800E+07	-.3110E+07
KTS	15.0	.4660E+07	.4550E+07	.4430E+07	.3500E+07	-.3500E+07	-.4430E+07	-.4550E+07	-.4660E+07
	20.0	.4980E+07	.4700E+07	.4420E+07	.3320E+07	-.3320E+07	-.4420E+07	-.4700E+07	-.4980E+07
	25.0	.6480E+07	.5670E+07	.4860E+07	.3240E+07	-.3240E+07	-.4860E+07	-.5670E+07	-.6480E+07
	28.0	.5690E+07	.5690E+07	.5690E+07	.4070E+07	-.4070E+07	-.5690E+07	-.5690E+07	-.5690E+07

TABLE A5 (Continued)

CASE A

TABLE OF RUDDER N VALUES

RUDDER ANGLE - DEG

		-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
	0.0	0.	0.	0.	0.	0.	0.	0.	0.
	5.0	.4020E+07	.3820E+07	.3630E+07	.2980E+07	-.2980E+07	-.3630E+07	-.3820E+07	-.4020E+07
SPEED	10.0	.1920E+08	.1740E+08	.1560E+08	.1400E+08	-.1400E+08	-.1560E+08	-.1740E+08	-.1920E+08
KTS	15.0	.2100E+08	.2040E+08	.1980E+08	.1870E+08	-.1870E+08	-.1980E+08	-.2040E+08	-.2100E+08
	20.0	.2490E+08	.2280E+08	.2070E+08	.1870E+08	-.1870E+08	-.2070E+08	-.2280E+08	-.2490E+08
	25.0	.1950E+08	.1780E+08	.1620E+08	.1300E+08	-.1300E+08	-.1620E+08	-.1780E+08	-.1950E+08
	28.0	.1830E+08	.1830E+08	.1830E+08	.1830E+08	-.1830E+08	-.1830E+08	-.1830E+08	-.1830E+08

TABLE A5 (Continued)

CASE I

TABLE OF RUDDER X VALUES

RUDDER ANGLE - DEG

SPEED KTS		-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
	0.0	0.	0.	0.	0.	0.	0.	0.	0.
	5.0	-.1560E+06	-.1280E+06	-.1010E+06	-.6730E+06	.6730E+06	.1010E+06	.1280E+06	.1560E+06
SPEED	10.0	-.5460E+06	-.4000E+06	-.3540E+06	-.2130E+06	.2130E+06	.3540E+06	.4000E+06	.5460E+06
KTS	15.0	-.1040E+07	-.8300E+06	-.6220E+06	-.3190E+06	.3190E+06	.6220E+06	.8300E+06	.1040E+07
	20.0	-.1530E+07	-.1120E+07	-.7080E+06	-.4250E+06	.4250E+06	.7080E+06	.1120E+07	.1530E+07
	25.0	-.1770E+07	-.1310E+07	-.8410E+06	-.4430E+06	.4430E+06	.8410E+06	.1310E+07	.1770E+07
	28.0	-.1670E+07	-.1150E+07	-.7220E+06	-.3890E+06	.3890E+06	.7220E+06	.1190E+07	.1670E+07

TABLE A6 Hydrodynamic Data for Strut Rudder at Deep Draft

CASE I

TABLE OF RUDDER Y VALUES

RUDDER ANGLE - DEG

		-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
	0.0	0.	0.	0.	0.	0.	0.	0.	0.
	5.0	-.4250E+06	-.3900E+06	-.3540E+06	-.3000E+06	.3000E+06	.3540E+06	.3900E+06	.4250E+06
SPEED	10.0	-.1300E+07	-.1210E+07	-.1130E+07	-.8990E+06	.8990E+06	.1130E+07	.1210E+07	.1300E+07
KTS	15.0	-.2070E+07	-.1910E+07	-.1750E+07	-.1390E+07	.1390E+07	.1750E+07	.1910E+07	.2070E+07
	20.0	-.2690E+07	-.2480E+07	-.2270E+07	-.1760E+07	.1760E+07	.2270E+07	.2480E+07	.2690E+07
	25.0	-.2170E+07	-.1900E+07	-.1640E+07	-.1150E+07	.1150E+07	.1640E+07	.1900E+07	.2170E+07
	28.0	-.1390E+07	-.1310E+07	-.1220E+07	-.8380E+06	.8380E+06	.1220E+07	.1310E+07	.1390E+07

TABLE A6 (Continued)

CASE I

TABLE OF RUDDER K VALUES

RUDDER ANGLE - DEG

SPEED KTS	-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
0.0	0.	0.	0.	0.	0.	0.	0.	0.
5.0	.5660E+06	.5120E+06	.4570E+06	.3590E+06	-.3590E+06	-.4570E+06	-.5120E+06	-.5660E+06
10.0	.2700E+07	.2440E+07	.2180E+07	.1710E+07	-.1710E+07	-.2180E+07	-.2440E+07	-.2700E+07
15.0	.8050E+07	.7230E+07	.6410E+07	.4660E+07	-.4660E+07	-.6410E+07	-.7230E+07	-.8050E+07
20.0	.9950E+07	.9020E+07	.8090E+07	.6220E+07	-.6220E+07	-.8090E+07	-.9020E+07	-.9950E+07
25.0	.8750E+07	.7940E+07	.7130E+07	.5510E+07	-.5510E+07	-.7130E+07	-.7940E+07	-.8750E+07
28.0	.6130E+07	.5560E+07	.4990E+07	.3850E+07	-.3850E+07	-.4990E+07	-.5560E+07	-.6130E+07

TABLE A6 (Continued)

CASE 5

TABLE OF RUDDER F VALUES

RUDDER ANGLE - DEG

SPEED KTS	-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
0.0	0.	0.	0.	0.	0.	0.	0.	0.
5.0	.5910E+07	.5570E+07	.5220E+07	.3920E+07	-.3920E+07	-.5220E+07	-.5570E+07	-.5910E+07
10.0	.2950E+08	.2720E+08	.2490E+08	.1870E+08	-.1870E+08	-.2490E+08	-.2720E+08	-.2950E+08
15.0	.4550E+08	.4080E+08	.3610E+08	.3030E+08	-.3030E+08	-.3610E+08	-.4080E+08	-.4550E+08
20.0	.4770E+08	.4480E+08	.4150E+08	.3320E+08	-.3320E+08	-.4150E+08	-.4480E+08	-.4770E+08
25.0	.4540E+08	.4050E+08	.3560E+08	.2920E+08	-.2920E+08	-.3560E+08	-.4050E+08	-.4540E+08
28.0	.4270E+08	.3810E+08	.3350E+08	.2740E+08	-.2740E+08	-.3350E+08	-.3810E+08	-.4270E+08

TABLE A6 (Continued)

CASE C

TABLE OF RUDDER Y VALUES

RUDDER ANGLE - DEG

		-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
	0.0	0.	0.	0.	0.	0.	0.	0.	0.
	5.0	-.9740E+05	-.8320E+05	-.6730E+05	-.4070E+05	.4070E+05	.6730E+05	.8320E+05	.9740E+05
SPEED	10.0	-.3400E+06	-.2760E+06	-.2190E+06	-.1270E+06	.1270E+06	.2190E+06	.2760E+06	.3400E+06
KTS	15.0	-.6370E+06	-.5100E+06	-.3820E+06	-.2070E+06	.2070E+06	.3820E+06	.5100E+06	.6370E+06
	20.0	-.9350E+06	-.7640E+06	-.5660E+06	-.2830E+06	.2830E+06	.5660E+06	.7640E+06	.9350E+06
	25.0	-.9740E+06	-.7520E+06	-.5750E+06	-.2660E+06	.2660E+06	.5750E+06	.7520E+06	.9740E+06
	28.0	-.9440E+06	-.6660E+06	-.5550E+06	-.2770E+06	.2770E+06	.5550E+06	.6660E+06	.9440E+06

TABLE A7 Hydrodynamic Data for Spade Rudder at Design Draft

CASE C

TABLE OF RUDDER Y VALUES

RUDDER ANGLE - DEG

		-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
	0.0	0.	0.	0.	0.	0.	0.	0.	0.
	5.0	-.1840E+06	-.1670E+06	-.1500E+06	-.1200E+06	.1200E+06	.1500E+06	.1670E+06	.1840E+06
SPEED	10.0	-.6510E+06	-.6720E+06	-.6940E+06	-.5310E+06	.5310E+06	.6940E+06	.6720E+06	.6510E+06
KTS	15.0	-.1230E+07	-.1370E+07	-.1310E+07	-.8760E+06	.8760E+06	.1310E+07	.1370E+07	.1230E+07
	20.0	-.1670E+07	-.1810E+07	-.1950E+07	-.1440E+07	.1440E+07	.1950E+07	.1810E+07	.1670E+07
	25.0	-.1950E+07	-.1950E+07	-.1770E+07	-.1150E+07	.1150E+07	.1770E+07	.1950E+07	.1950E+07
	28.0	-.1940E+07	-.1660E+07	-.1380E+07	-.1110E+07	.1110E+07	.1380E+07	.1660E+07	.1940E+07

TABLE A7 (Continued)

CASE C

TABLE OF RUDDER K VALUES

RUDDER ANGLE - DEG

		-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
	0.0	0.	0.	0.	0.	0.	0.	0.	0.
	5.0	.1040E+07	.9060E+06	.7770E+06	.5180E+06	-.5180E+06	-.7770E+06	-.9060E+06	-.1040E+07
SPEED	10.0	.3000E+07	.3110E+07	.3000E+07	.2590E+07	-.2590E+07	-.3000E+07	-.3110E+07	-.3000E+07
KTS	15.0	.5600E+07	.6180E+07	.5600E+07	.4430E+07	-.4430E+07	-.5600E+07	-.6180E+07	-.5600E+07
	20.0	.8700E+07	.9740E+07	.9740E+07	.7880E+07	-.7880E+07	-.9740E+07	-.9740E+07	-.8700E+07
	25.0	.9070E+07	.9070E+07	.9070E+07	.6480E+07	-.6480E+07	-.9070E+07	-.9070E+07	-.9070E+07
	30.0	.6900E+07	.6900E+07	.6900E+07	.6900E+07	-.6900E+07	-.6900E+07	-.6900E+07	-.6900E+07

TABLE A7 (Continued)

CASE C

TABLE OF RUDDER N VALUES

RUDDER ANGLE - DEG

		-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
	0.0	0.	0.	0.	0.	0.	0.	0.	0.
	5.0	.4270E+07	.4270E+07	.4270E+07	.3110E+07	-.3110E+07	-.4270E+07	-.4270E+07	-.4270E+07
SPEED	10.0	.1920E+08	.2620E+08	.1920E+08	.1550E+08	-.1550E+08	-.1920E+08	-.2920E+08	-.1920E+08
KTS	15.0	.3030E+08	.3500E+08	.3380E+08	.2800E+08	-.2800E+08	-.3380E+08	-.3500E+08	-.3030E+08
	20.0	.6630E+08	.7250E+08	.6010E+08	.4140E+08	-.4140E+08	-.6010E+08	-.7250E+08	-.6630E+08
	25.0	.5500E+08	.5500E+08	.5500E+08	.3240E+08	-.3240E+08	-.5500E+08	-.5500E+08	-.5500E+08
	28.0	.4260E+08	.4260E+08	.4260E+08	.3940E+08	-.3940E+08	-.4260E+08	-.4260E+08	-.4260E+08

TABLE A7 (Continued)

CASE D

TABLE OF RUDDER X VALUES

RUDDER ANGLE - DEG

		-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
	0.0	0.	0.	0.	0.	0.	0.	0.	0.
	5.0	-.1240E+06	-.1030E+06	-.7970E+05	-.4780E+05	.4780E+05	.7970E+05	.1030E+06	.1240E+06
SPEED	10.0	-.4600E+06	-.3890E+06	-.2830E+06	-.1560E+06	.1560E+06	.2830E+06	.3890E+06	.4600E+06
KTS	15.0	-.1040E+07	-.8750E+06	-.6370E+06	-.3510E+06	.3510E+06	.6370E+06	.8750E+06	.1040E+07
	20.0	-.1420E+07	-.1160E+07	-.8780E+06	-.4810E+06	.4810E+06	.8780E+06	.1160E+07	.1420E+07
	25.0	-.1770E+07	-.1420E+07	-.1020E+07	-.5310E+06	.5310E+06	.1020E+07	.1420E+07	.1770E+07
	28.0	-.2000E+07	-.1610E+07	-.1170E+07	-.6110E+06	.6110E+06	.1170E+07	.1610E+07	.2000E+07

TABLE A8 Hydrodynamic Data for Spade Rudder at Deep Draft

CASE D

TABLE OF RUDDER Y VALUES

RUDDER ANGLE - DEG

		-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
	0.0	0.	0.	0.	0.	0.	0.	0.	0.
	5.0	-.3010E+06	-.3010E+06	-.3010E+06	-.2100E+06	.2100E+06	.3010E+06	.3910E+06	.3010E+06
SPEED	10.0	-.1060E+07	-.1060E+07	-.1060E+07	-.8070E+06	.8070E+06	.1060E+07	.1060E+07	.1060E+07
KTS	15.0	-.2040E+07	-.2040E+07	-.1950E+07	-.1320E+07	.1320E+07	.1990E+07	.2040E+07	.2040E+07
	20.0	-.3230E+07	-.3230E+07	-.3120E+07	-.2260E+07	.2260E+07	.3120E+07	.3230E+07	.3230E+07
	25.0	-.2660E+07	-.2790E+07	-.2790E+07	-.1900E+07	.1900E+07	.2790E+07	.2790E+07	.2660E+07
	28.0	-.2390E+07	-.2510E+07	-.2510E+07	-.1710E+07	.1710E+07	.2510E+07	.2510E+07	.2390E+07

TABLE A8 (Continued)

CASE F

TABLE OF RUDDER F VALUES

RUDDER ANGLE - DEG

		-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
	0.0	0.	0.	0.	0.	0.	0.	0.	0.
	5.0	.8030E+06	.8120E+06	.7360E+06	.5330E+06	-.5330E+06	-.7360E+06	-.9120E+06	-.8030E+06
SPEED	10.0	.3110E+07	.3210E+07	.2900E+07	.2070E+07	-.2070E+07	-.2900E+07	-.3210E+07	-.3110E+07
KTS	15.0	.6760E+07	.7000E+07	.6060E+07	.4080E+07	-.4080E+07	-.6060E+07	-.7000E+07	-.6760E+07
	20.0	.1160E+08	.1200E+08	.1040E+08	.7880E+07	-.7880E+07	-.1040E+08	-.1200E+08	-.1160E+08
	25.0	.1550E+08	.1620E+08	.1360E+08	.1040E+08	-.1040E+08	-.1360E+08	-.1620E+08	-.1550E+08
	28.0	.1700E+08	.1790E+08	.1540E+08	.1140E+08	-.1140E+08	-.1540E+08	-.1790E+08	-.1700E+08

TABLE A8 (Continued)

CASE D

TABLE OF RUDDER N VALUES

RUDDER ANGLE - DEG

SPEED KTS	-40.0	-35.0	-30.0	-20.0	20.0	30.0	35.0	40.0
0.0	0.	0.	0.	0.	0.	0.	0.	0.
5.0	.5130E+07	.6200E+07	.7290E+07	.4910E+07	-.4910E+07	-.7290E+07	-.6200E+07	-.5130E+07
10.0	.2490E+08	.2640E+08	.2740E+08	.2380E+08	-.2380E+08	-.2740E+08	-.2640E+08	-.2490E+08
15.0	.4660E+08	.4900E+08	.5130E+08	.3730E+08	-.3730E+08	-.5130E+08	-.4900E+08	-.4660E+08
20.0	.7870E+08	.7670E+08	.7460E+08	.5600E+08	-.5600E+08	-.7460E+08	-.7670E+08	-.7870E+08
25.0	.7450E+08	.7450E+08	.7450E+08	.5830E+08	-.5830E+08	-.7450E+08	-.7450E+08	-.7450E+08
28.0	.6690E+08	.6690E+08	.6690E+08	.5240E+08	-.5240E+08	-.6690E+08	-.6690E+08	-.6690E+08

TABLE A8 (Continued)

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APPENDIX B

PROGRAM LISTING

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```
      PROGRAM CVATH(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE2=512,
     1   TAPE7=512,TAPE8=512,TAPE9=512, TAPE11=512,TAPE1=512,TAPE10=512
     .   )
C
      COMMON /INTGRL/ DT,DTMIN,TMAX,AE(15),EPS(15),NSTATE
C
      COMMON /OUTX  / IBUS(5),NPRINT(5),JR ,NRUN ,NPRINT
      LOGICAL PRT,PRAUXS
      COMMON /PRPRNT/ IF1,IF2,IF3,IR4,IR5,IP1,IP2,IP3,IP4,IP5,IP6,IP7,
     1                IP8,IP9,IP10,PRT(15)
      COMMON /OPTION/ IDOF,IOPTN(20)
      DIMENSION F(13),Y(20)
      NRUNS = -1000
 1    CONTINUE
      CALL INPUT(Y,TIME)
      IF(NRUNS.EQ.NRUN) GO TO 999
      IF(NRUN.LE.0) GO TO 999
        NSTATE = 13

        NRUNS = NRUN
        FIRST = 0.0
        HCX   = DT
        IBUS(1) = 0
      PRAUXS=PRT(10)
C       BEGIN INTEGRATION LOOP
 100    CONTINUE
      PRT(10)=PRAUXS
      WRITE(IF9,640) TIME,HCX
  640 FORMAT(F10.2,F10.8)
C
C       INTEGRATE FROM TIME TO TIME + NPRINT*DT
        DO 200 I=1,NPRINT
         IF(IOPTN(1).EQ.0)CALL KUTMER(NSTATE,TIME,DT,Y,EPS,AE,HCX,FIRST
        IF(IOPTN(1).EQ.1) CALL EULER(TIME,DT,Y,NSTATE)
        IF(FIRST.GE.2) IBUS(1)=1
         IF(TIME.GT.TMAX) IBUS(1) = 1
          IF(IBUS(1).EQ.1) GO TO 210
 200    CONTINUE
C       PRINT OUTPUT AT INTERVALS OF DT*NPRINT
        CALL OUTPUT(1)
        IF(IBUS(1).EQ.1) GO TO 210
        GO TO 100
 210  CONTINUE
      PRT(10)=PRAUXS
      CALL OUTPUT(2)
C     COMPLETION OF RUN
      GO TO 1
 999  CONTINUE
      WRITE(IF6,644)
C
 644  FORMAT(47H ALL RUNS COMPLETED INTERMEDIATE PRINT FOLLOWS.)
C
      STOP
      END
```

```
      SUBROUTINE [illegible]LFOR
C
C     PROGRAM TO COMPUTE ACCELERATION AND ADDITIONAL RATE DEPENDENT FOR
C     [illegible]TS, EFFECTIVE MASS TYPE TERMS
C
      REAL LENGTH
      COMMON /AMASS/ AMTRX(6,6,6),ACCEL(6),RTMTRX(6,6)
      COMMON /STATE0/ T0,U0,V0,W0,P0,Q0,R0,PHI0,THETA0,PSI0
      COMMON /CONST / RADIAN, RHO[illegible], RHOA[illegible], RHO[illegible], RHOW[illegible],FTTI[illegible]4
      COMMON /STATE / U,V,W,P,Q,R,PHI,THETA,PSI,XE,YE,ZE,S,SPEED,
     1                DRIFT[illegible],COSPHI,COSTHE,COSPSI,SINPHI,SINTHE,SINPSI,
     2                TMTRX(3,3),TIME
      COMMON /CRAFT / SCFACT, LENGTH, MASS  ,IXX,IYY,IYZ, IXY,IXZ, IZZ
      LOGICAL PNT
      COMMON /PRINT/ IR1,IR2,IR3,IR4,IR5,IP1,IP2,IP3,IP4,IP5,IP6,IP7,
     1                IP8,IP9,IP10,PNT(15)
      DIMENSION MARR(6)
      MARR(1)=[illegible]
      MARR(2)=[illegible]
      MARR(3)=[illegible]
      MARR(4)=[illegible]
      MARR(5)=[illegible]
      MARR(6)=[illegible]
      DO 1 J=1,6
    1 ACCEL(J)=0.0
      DO 2 KK=1,6
      DO 2 N=1,6
      L=N
      DO 2 M=L,6
      KEXP=(N+M+[illegible])/3
      ACCEL(KK)=ACCEL(KK)+RHONO*(LENGTH**KEXP)*MARR(N)*MARR(M)*AMTRX
     1(KK,N,M)
    2 CONTINUE
      DO 3 L=1,6
      DO 3 M=1,6
      LEXP=(L+[illegible])/3
      ACCEL(L)=ACCEL(L)+RHONO*(LENGTH**LEXP)*MARR(M)*RTMTRX(L,M)
    3 CONTINUE
      RETURN
      END
```

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```
      SUBROUTINE AIRFOR
C
C     PROGRAM TO COMPUTE AERODYNAMIC FORCES AND MOMENTS
C
      COMMON /STATEO/ TO,UO,VO,WO,PO,QO,RO,PHIO,THETAO,PSIO
      COMMON /AIRFOR/ AIRFM(6)
C
      COMMON /CONST / RADIAN, RHOA, RHOAO, RHOS, RHOWS,FTTOM
      COMMON /STATE / U,V,W,P,Q,R,PHI,THETA,PSI,XE,YE,ZE,S,SPEED,
     .                DRIFAN,COSPHI,COSTHE,COSPSI,SINPHI,SINTHE,SINPSI
     .                TMTRX(3,3),TIME
C
C
      AIRFM(1) = 0.0
      AIRFM(2) = 0.0
      AIRFM(3) = 0.0
      AIRFM(4) = 0.0
      AIRFM(5) = 0.0
      AIRFM(6) = 0.0
C
C
      RETURN
      END
```

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```
      BLOCK DATA
      REAL LENGTH,MASS,IXX,IXY,IXZ,IYY,IYZ,IZZ,KPDOT,KRDOT,KVDOT,
     1     KQDOT,MQDOT,MWDOT,NRDOT,NVDOT,MSURZ,MSURTH
      COMMON /CRAFT / SCFACT, LENGTH, MASS  ,IXX,IXY,IXZ, IYY,IYZ, IZZ
C
      COMMON /CONST / RADIAN, RHOA, RHOA2, RHOW, RHOW2,ETTOM
C
      COMMON /STATE / U,V,W,P,Q,R,PHI,THETA,PSI,XE,YE,ZE,S,SPEED,
     1               TRIRAN,COSPHI,COSTHE,COSPSI,SINPHI,SINTHE,SINPSI,
     2               TMTRX(3,3),TIME
C
      COMMON/FINVAR/XFIN(4),YFIN(4),ZFIN(4),AREFIN(4),CLFIN(4),
     1CDREFIN(4),FINANG(4),XFORCE(4),YFORCE(4),ZFORCE(4),ALIFT(4),
     3DRAG(4),FF(4)
     4,FINMUC(4)
C
      COMMON /HYDRO / I6(4),L7,HY(4,3913),TF(4,16),Y6(4,20),IPRINT(4),
     1               UMAX,HYDREF(4),ICNT
C
C
      COMMON/RUDVAR/RUDANG(2),LEVEL(10),RALFA(10),AXRUD(100),AYRUD(100)
     1             AKRUD(100),ANRUD(100),ARATIO,RUDAN0(2),NUMUUV,NUMRAL
     1               RUDRCN,RRUDAR,RRUDAR,RERCRN,RUDFM(6)
     1,XRUD(2),YRUD(2),ZRUD(2)
     1,RUDMAX
     1,RRDARM,RRCRM
C
      COMMON /PROPVR/ RDIA, PROARM(3), PRPAS, SHFMR, PITCHS, PITCHR,
     *               PROPFM(6)
C
      COMMON /AIRVAR/ AIRFM(6)
C
      COMMON/HULVAR/HULLFM(6),HULPTK
C
      COMMON/BOYVAR/MSURZ,MSURTH,ZSURZ,ZSURTH,BUOYFM(6)
C
      COMMON/ADDVAR/ADMTRX(6,6,6),ADDFM(6),RINTRX(6,6)
      COMMON/ DTCOE/XUDOT,YVDOT,YRDOT,YRDOT,ZWDOT,ZQDOT,KVDOT,KPDOT,
     *            KRDOT,MWDOT,MQDOT,NVDOT,NPDOT,NRDOT
C
      COMMON/COMMOVE/XC,YC,ZC
      LOGICAL PRT
C
      COMMON /PRPRNT/ IR1,IR2,IR3,IR4,IR5,IP1,IP2,IP3,IP4,IP5,IP6,IP7,
     1               IP8,IP9,IP10,PNT(15)
C
      COMMON /OPTION/ IDOF,IOPTN(20)
C
      COMMON /STATE0/ T0,U0,V0,W0,P0,Q0,R0,PHI0,THETA0,PSI0
C
      COMMON /INTGRL/ DT,DTMIN,TMAX,AE(15),RE(15),NSTATE
C
C         DT             - STEP SIZE FOR CALLS TO KUTMER, SEC
C         DTMIN          - MINIMUM STEP SIZE TO BE USED BY KUTMER, SEC
C         TMAX           - SIMULATION STOP TIME
C         AE(1-15)       - ABSOLUTE INTEGRATION ERROR CRITERIA FOR STATE
C                          VECTOR, Y(1-15)
```

```
C        EPS(1-15)       - RELATIVE ERROR CRITERIA FOR Y(1-15)
C
      COMMON /CONTRL/ ICONT,IC1(10),IC2(10),IACT(10),JACT(10),CV1(10),
     1                CV2(10),CV3(10),CV4(10),CRIT1(10),CRIT2(10),
     2                CRIT 1(10),COIN2(10),COIN3(10),FFLAG(2),CHECK(2),
     3                SATF(10),KACT(10)
      COMMON /OUTP  / IFOP(5),IPRINT(5),JR ,NFLI ,NPRINT
C
      COMMON /HEADER/ TITLE(10)
C
      DATA BRULAS/0./,TRUTAR/0./
C
      DATA XFUF/2*-21.0437/,YFUF/11.47,-11.47/,ZFUF/2*3.1515/
      DATA (TITLE(I),I=1,10) /10*1H /, NPRINT/1/
      DATA SCFACT/33.5/,LENGTH/73.15/,MASS/2.9E+06/,IXX/8.4984E+08/,
     1IYY/4.2760/,IZZ/4.2760E+09/,
     2     IXY /0.0     /,  IXZ/0.0     /,  IYZ/0.0/
C
       DATA DEGRAD /57.2 57795 1/, RHOA/1.25/, RHOA2/0.645/, RHOW/1000./
     1    ,RHOW2/500./, PITCH/.7046/
C
      DATA U/00.0/,V,W,P,Q,R,PHI,THETA,PSI,XE,YE,ZE,DRIFAN/12*0.0/,
     1    SETPD/11.0/, COSPHI,COSTHE,COSPSI /3*1.0/, TIME /0.0/,
     2    SINPHI,SINTHE,SINPSI /3*0.0/, TMTRX /1.,0.,0.,0.,1.,0.,0.,0.,
     3    1./
C
      DATA TC/0./,UC/20./,VC/0./,PC/0./,QC/0./,FN/0./,MC/0./,
     1    PHI /0./, THETA /0./, PSI /0./
C
      DATA KRDOT/-1.344E+06/
      DATA YVDOT,NRDOT,YRDOT,NVDOT,YPDOT,KVDOT,LPDOT,KRDOT/
     1-1.214E+07,-2.944E+10,0,-2.154E+06,0,-4.135E+07,
     200,-5.777E+06/
C
      DATA ATHRM/6*0.0/,S/2.4/
C
      DATA XUDOT,ZWDOT,ZQDOT,MWDOT,MQDOT/5*0.0/
C
      DATA UMAX/1.0/,LZ/0/
C
      DATA RSIM/4.34/,PRDLMY/-30.70,11.43,-.06/,PRPMSD/150./,
     1PRPMPG/150./,PTCHSD/1.07/,PTCHPD/1.07/
C
      DATA XFIN/2*19.4316,2*-26.6309/,YFIN/7.7627,-7.7627,7.7627,
     1    -7.7627/,
     2    ZFIN/4*3.0619/,ASATIN/2*7.544,2*22.5057/,CLFIN/4*1.13/
C
       DATA ZSURZ,ZSURTH,MSURZ,MSURTH/-2001096.,2*434374.,-2761917./
C
      DATA RUDARM/4.0/
      DATA ARMPR /13.55/,HDDRAM/6.99/
      DATA ULVEL/0., .0,.578,5.144,7.716,10.288,12.86,14.407/
      DATA DALTA/-.7,-.611,-.504,-.349,.349,.504,.611,.7/
      DATA XC/0.0/,YC/0.0/,ZC/0.0/
      DATA AXPRO/100*0.0/,YPRO /100*0.0/,AXPRUD/100*0.0/,AYPRUD/100*0.0/
      DATA NUMVAL/8/,NUMUDV/7/,ARATIO/1.0/,HULFIK/0./
      DATA IR1,IR2,IR3,IR4,IR5/5*5/,IP1/6/,IP2/8/,
```

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```
1        IP3/6/, IP4/6/, IP5/6/, IP6/6/, IP7/6/, IP8/6/, IP9/6/,
2              IP10/10/
C
      DATA IP E /6/, IOPT /00*0/
C
      DATA DAT/15*.FALSE./
C
      DATA DT,DTMIN,TMAX/3.0,.0312,200./,AF/1.,0*.5,.0005,0*.002,
     1.001,0*.100,2*5.,.001,0*5.,.01/,IPC/15*.15/
C
      DATA IC AT /0/, (CRIT1(I),I=1,16) /1HU,1HV,1HW,1HP,1HQ,1HR,
     1      HROLL ANGLES,7HPITCH ANG,9HYAW ANGLE,2HXE,2HYE,2HZE,
     2      8HDISTANCE,5HSPEED,3HDEG,4HTIME/
C
      DATA (CRIT2(I),I=1,16)/ 5HM/SEC,5HM/SEC,5HM/SEC,7HDEG/SEC,
     1      7HDEG/SEC,7HDEG/SEC,3*3HDEG,4*6HMETERS,5HM/SEC,
     2      3HDEG,3HSEC/
C
      DATA (REL(I),I=1,2)/4H.GT.,4HL.T./
C
      DATA (CRIT3(I),I=1,12) /6HRPM-STBD, HRPM-PORT,9HP-PITCH-S,
     1      9HP-PITCH-P,9HRUD-FOW-S,9HRUD-FOW-P,9HRUD-AFT-S,9HRUD-AFT-P,
     2      9HFIN-FOW-S,9HFIN-FOW-P,9HFIN-AFT-S,9HFIN-AFT-P/
C
      DATA (CRIT4(I),I=1,12)/2*3HRPM,10*7HDEG/
C
      DATA (CRIT5(I),I=1,12) /2*7HRPM/SEC,10*7HDEG/SEC/
C
      DATA   (CHECK(I),I=1,2)   /4HONCE,10HCONSTANTLY/
C
      DATA (RATE(I),I=1,12) / 2*100.,10*5.0/
C
C     DEFINITION OF FORTRAN SYMBOLS
C     DESCRIPTION OF VARIABLES APPEARING IN NAMED COMMON
C
C                  COMMON /AIRVAR /
C        AIRFM(1-3)        - AIR RESISTANCE X,Y,Z FORCES ALONG BODY AXES
C        AIRFM(4-6)        - AIR K,M,N MOMENTS ABOUT BODY AXES
C                  COMMON /ADDVAR /
C        ADMTRX(6,6,6)     - MATRIX OF RATE DEPENDENT 2ND ORDER TERMS FOR
C     HULL FORCES
C        ADDFM(1-3)        - RATE DEPENDENT X,Y,Z FORCES
C        ADDFM(4-6)        - RATE DEPENDENT K,M,N MOMENTS
C        RTMTRX(6,6)       - MATRIX OF 1ST ORDER RATE DEPENDENT TERMS FOR
C     HULL FORCES
C
C                  COMMON /BOYVAR /
C        MQUEB             - RESTORING DERIVATIVE MZ DUE TO BUOYANCY
C        MQUETH            - RESTORING DERIVATIVE MQ DUE TO BUOYANCY
C        ZQUEZ             - RESTORING DERIVATIVE ZZ DUE TO BUOYANCY
C        ZQUETH            - RESTORING DERIVATIVE ZQ DUE TO BUOYANCY
C        BUOYFM(1-3)       - BUOYANCY X,Y,Z FORCES ALONG BODY AXES
C        BUOYFM(4-6)       - BUOYANCY K,M,N MOMENTS ABOUT BODY AXES
C
C                  COMMON /CGMOVE /
C        XG,YG,ZG          - X,Y,Z COORDINATES OF CENTER OF GRAVITY
C
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C                        COMMON /CRAFT /
C       SCFACT            - SHIP-MODEL SCALE FACTOR
C       LENGTH            - SHIP LENGTH
C       MASS              - SHIP MASS
C       IXX,IYY,IZZ       - SHIP MOMENTS OF INERTIA
C       IXY,IYZ,IXZ       - SHIP PRODUCTS OF INERTIA
C
C                        COMMON /CONST /
C       DEGRAD            - NUMBER OF DEGREES PER RADIAN, 57.29
C       RHOA              - DENSITY OF AIR
C       RHOA2             - 1/2 OF RHOA
C       RHOW              - DENSITY OF WATER
C       RHOW2             - 1/2 OF RHOW
C       FTTOM             - CONVERSION FEET TO METERS
C
C                        COMMON /DOTCOE /
C       XUDOT             - DIMENSIONAL COEFFICIENT XU
C       YVDOT             - DIMENSIONAL COEFFICIENT YV
C       YPDOT             - DIMENSIONAL COEFFICIENT YP
C       YRDOT             - DIMENSIONAL COEFFICIENT YR
C       ZWDOT             - DIMENSIONAL COEFFICIENT ZW
C       ZQDOT             - DIMENSIONAL COEFFICIENT ZQ
C       KVDOT             - DIMENSIONAL COEFFICIENT KV
C       KPDOT             - DIMENSIONAL COEFFICIENT KP
C       KRDOT             - DIMENSIONAL COEFFICIENT KR
C       MWDOT             - DIMENSIONAL COEFFICIENT MW
C       MQDOT             - DIMENSIONAL COEFFICIENT MQ
C       NVDOT             - DIMENSIONAL COEFFICIENT NV
C       NRDOT             - DIMENSIONAL COEFFICIENT NR
C
C                        COMMON /FINVAR /
C       XFIN(1-4)         - X,Y,Z COORDINATES OF FIN CENTER OF
C       YFIN(1-4)         - PRESSURE 1 = BOW STARBOARD, 2 = BOW PORT,
C       ZFIN(1-4)         - 3 = AFT STARBOARD, 4 = AFT PORT
C       AREFIN(1-4)       - AREAS OF FINS
C       CLFIN(1-4)        - LIFT COEFFICIENT OF FINS
C       RDFIN(1-4)        - LIFT/DRAG RATIO OF FINS
C       FINANG(1-4)       - FIN ANGLES
C       XFORFN(1-4)       - FIN X,Y,Z FORCES IN BODY
C       YFORFN(1-4)       - FIN X,Y,Z FORCES IN BODY
C       ZFORFN(1-4)       - FIN X,Y,Z FORCES IN BODY
C       ALIFT(1-4)        - FIN LIFT AND DRAG
C       DRAG(1-4)         - FIN LIFT AND DRAG
C       FFM(1-3)          - FIN X,Y,Z FORCES IN BODY SYSTEM
C       FFM(4-6)          - FIN K,M,N MOMENTS
C       FINANI(1-4)       - INITIAL FIN ANGLES
C
C                        COMMON /HULVAR /
C       HULLFM(1-3)       - HULL X,Y,Z FORCES ALONG BODY AXES
C       HULLFM(4-6)       - HULL K,M,N MOMENTS ABOUT BODY AXES
C       HULFIX            - DIFFERENCE IN DRAFT FROM DESIGN CONDITION,
C    DEEPER DRAFT=POSITIVE
C
C                        COMMON /HYDRO /
C       LP(4)             - NUMBER OF GRID POINTS FOR HYDINT
C       LZ                - NUMBER OF ZERO SPEED CURVES
C       HY(4,2213)        - DATA POINTS FOR HYDINT ARRAY
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C        XGRH( ,2)          - GRID POINTS FOR HYDIAT ARRAY
C        POINT(4)           - POINTER FOR HYDINT
C
C                 COMMON /INTGRL /
C        DT                 - STEP SIZE FOR INTEGRATION PROCEDURE
C        DTMIN              - MINIMUM STEP SIZE FOR KUTMER
C        TMAX               - MAXIMUM TIME FOR RUN
C        ABSERR             - ABSOLUTE ERROR CRITERION FOR KUTMER
C     INTEGRATION
C        RELERR             - RELATIVE ERROR CRITERION FOR KUTMER
C     INTEGRATION
C        NSTATE             - NUMBER OF STATE VARIABLES
C                 COMMON /OPTION /
C        IDOF               - DEGREES OF FREEDOM
C        IOPT (1-15)        - IOPT(1)=0, KUTMER INTEGRATION
C        IOPT(1)=1, EULER INTEGRATION
C        IOPT (2)=0, DO NOT PRINT PAGES 3-5
C        IOPT(2)=1, PRINT PAGES 3-5, RUDDER, PROP, FIN FORCES
C
C                 COMMON /PROPMP /
C        PDIA               - PROP DIAMETER
C        XYZPRP(1-3)        - PROP X,Y,Z COORDINATES
C        PRPMS              - PROP RPM STARBOARD
C        PRPMP              - PROP RPM PORT
C        PITCHS             - PITCH/DIAMETER RATIO - STARBOARD
C        PITCHP             - PITCH/DIAMETER RATIO - PORT
C        PROPFB(1-3)        - PROP X,Y,Z FORCES ALONG BODY AXES
C        PROPFB(4-6)        - PROP K,M,N MOMENTS ABOUT BODY AXES
C        PTCHSO             - P/D RATIO - STARBOARD, INITIAL
C        PTCHPO             - P/D RATIO - PORT, INITIAL
C
C
C
C
C
C
C        IR(1-5)            - READ UNITS
C        IP(6-10)           PRINT UNITS 6 = MAIN OUTPUT PRINTER
C        UNIT(15)           - OPTIONAL-DEBUGGING OUTPUT, 9 = HYDRO ARRAY
C     10 = INTERMEDIATE FORCE-MOMENT TIME HISTORIES
C
C                 COMMON /RUDVAR /
C        RUDANG(2)          - SET RUDDER ANGLES, 1=STARBOARD, 2=PORT
C        RUVEL(10)          - GRID VELOCITY ARRAY FOR RUDDER FORCES
C        RALFA(10)          - GRID RUDDER ANGLE ARRAY FOR RUDDER FORCES
C        XRUD(100)          - X RUDDER FORCE ARRAY
C        YRUD(100)          - Y RUDDER FORCE ARRAY
C        KRUD(100)          - K RUDDER MOMENT ARRAY
C        NRUD               - N RUDDER MOMENT ARRAY
C        ARATIO             - RUDDER SIZING RATIO, TO STANDARD RUDDER
C        RUDANI(2)          - RUDDER ANGLES AT INITIAL TIME
C        NUMVEL             - NUMBER OF DATA GRID VELOCITY POINTS
C        NUMANG             - NUMBER OF DATA GRID RUDDER ANGLE POINTS
C        RRUDAS             - STARBOARD ROW RUDDER POSITION
C        RRUDAP             - PORT ROW RUDDER POSITION
C        RUDF (1-3)         - RUD TR X,Y,Z FORCES IN BODY SYSTEM
C        RUDF (4-6)         - RUDDER K,M,N MOMENTS ABOUT BODY AXES
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C         XRUD(2)          - X COORDINATES OF AFT RUDDER CENTER OF
C       PRESSURE
C         YRUD(2)          - Y COORDINATES OF AFT RUDDER CENTER OF
C       PRESSURE
C         ZRUD(2)          - Z COORDINATES OF AFT RUDDER CENTER OF
C       PRESSURE
C         ARMAFT           - AFT RUDDER PITCH MOMENT ARM
C         ARMBOW           - BOW RUDDER PITCH MOMENT ARM
C         BSPAN            - MAXIMUM BOW RUDDER EXTENDED LENGTH
C
C                     COMMON /STATE /
C         U,V,W            - SHIP VELOCITY COMPONENTS IN BODY COORDINATE
C       SYSTEM
C         P,Q,R            - SHIP ANGULAR VELOCITY ABOUT BODY AXES
C         PHI              - ROLL ANGLE
C         THETA            - PITCH ANGLE
C         PSI              - YAW ANGLE
C         XE,YE,ZE         - SHIP POSITION IN FIXED SPACE COORDINATES
C         S                - DISTANCE TRAVELLED
C         SPEED            - SHIP SPEED
C         DRIFTA           - DRIFT ANGLE
C         COSPHI
C         COSTHE           - COSINES OF PHI,THETA,PSI
C         COSPSI
C         SINPHI
C         SINTHE           - SINES OF PHI,THETA,PSI
C         SINPSI
C         TMTRX(3,3)       - TRANSFORMATION MATRIX FROM FIXED SYSTEM TO
C       BODY SYSTEM
C         TIME             - TIME
C
C                     COMMON /STATE0 /
C         T0               - INITIAL TIME
C         U0               - INITIAL VALUES OF U,V,W,P,Q,R,PHI,THETA,PSI
C         V0               - INITIAL VALUES OF U,V,W,P,Q,R,PHI,THETA,PSI
C         W0               - INITIAL VALUES OF U,V,W,P,Q,R,PHI,THETA,PSI
C         P0               - INITIAL VALUES OF U,V,W,P,Q,R,PHI,THETA,PSI
C         Q0               - INITIAL VALUES OF U,V,W,P,Q,R,PHI,THETA,PSI
C         R0               - INITIAL VALUES OF U,V,W,P,Q,R,PHI,THETA,PSI
C         PHI0             - INITIAL VALUES OF U,V,W,P,Q,R,PHI,THETA,PSI
C         THETA0           - INITIAL VALUES OF U,V,W,P,Q,R,PHI,THETA,PSI
C         PSI0             - INITIAL VALUES OF U,V,W,P,Q,R,PHI,THETA,PSI
        END
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      SUBROUTINE BOYFOR
C     BOYFOR COMPUTES FORCES AND MOMENTS DUE TO BUOYANCY
      REAL MSURTH,MSURZ
      COMMON /STATE/ U,V,W,P,Q,R,PHI,THETA,PSI,XE,YE,ZE,SPEED,C,DRIFAN,
     *COSPHI,COSTHE,COSPSI,SINPHI,SINTHE,SINPSI,TMTRX(3,3),TIME
      COMMON /BOYVAR/ MSURZ, MSURTH ,ZSURZ, ZSURTH, BUOYFM(6)
      COMMON /DEVPR/DELTA,FROARM(3),PROPNS,PROPNP,PITCHS,PITCHP,PROPFM(6)
C     MSURZ  -  DIMENSIONALIZED COEFFICIENT M SUB ZE
C     MSURTH -  DIMENSIONALIZED COEFFICIENT M SUB THETA
C     ZSURZ  -  DIMENSIONALIZED COEFFICIENT Z FORCE SUB ZE
C     ZSURTH -  DIMENSIONALIZED COEFFICIENT Z FORCE SUB THETA
C     BUOYFM(1-3) - BUOYANCY FORCES ALONG BODY X,Y,Z AXES
C     BUOYFM(4-6) - BUOYANCY MOMENTS ABOUT BODY AXES
      AZFIX     =ZSURZ*ZE+ZSURTH*THETA
      AKFIX=(FROARM(2)**2.)*TAN(PHI)*ZSURZ
      AMFIX     =MSURZ*ZE+MSURTH*THETA
      BUOYFM(1)=0.0
      BUOYFM(2)=0.0
      BUOYFM(3)=AZFIX
      BUOYFM(4)=AKFIX
      BUOYFM(5)=AMFIX
      BUOYFM(6)=0.0
      RETURN
      END
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```
      SUBROUTINE CONTRL(T,Y)
C
C     PILOT ACTION ROUTINE. LINEAR INTERPOLATION IS USED TO DETERMINE
C     CONTROL SURFACE TIME HISTORIES
C
      DIMENSION STAT(12),CONV(16),A(12,16),Y(17)
      DIMENSION CONACT(10)
C
C     CONV   -  CONVERSION FACTORS TO CONVERT INTERNAL UNITS TO UNITS
C               AS READ I .(APPLIED TO STATE VECTOR)
C
C
      REAL LENGTH,MASS,IXX,IXY,IXZ,IYY,IYZ,IZZ,KPDOT,KRDOT,KVDOT,
     1     MPDOT,MWDOT,NRDOT,NPDOT,NVDOT,MSUBZ,MSUBTH
      COMMON /CRAFT / CCFACT, LENGTH, MASS  ,IXX,IXY,IXZ, IYY,IYZ, IZZ
C
      COMMON /CONST / RADIAN, RHOA, RHOA2, RHOW, RHOW2,FTTOM
C
      COMMON /STATE / U,V,W,P,Q,R,PHI,THETA,PSI,XE,YE,ZE,S,SPEED,
     1                DRIFAN,COSPHI,COSTHE,COSPSI,SINPHI,SINTHE,SINPSI,
     2                TMTRX(3,3),TIME
C
      COMMON/FINVAR/XFIN(4),YFIN(4),ZFIN(4),SPAFIN(4),CLFIN(4),
     CDFIN(4),FINANG(4),XFORFM(4),YFORFM(4),ZFORFM(4),ALIFT(4),
     3DRAG(4),FFM(6)
     4,FINANC(4)
C
      COMMON /HYDRO / LS(4),LT,HY(4,3217),FF(4,16),C(4,20),IPRINT(4),
     1                NMAX,HYDRFM(6),ICNT
C
C
      COMMON/RUDVAR/RUDANG(2),UUVTL(10),RALFA(10),AXRUD(100),AYRUD(100),
     1              AKRUD(100),AMRUD(100),ARATIO,RUDAND(2),NUMUUV,NUMRAL,
     1                RUDFSN,FRUDAS,FRUDAP,RRDSEN,RUDFM(6)
     1,XRUD(2),YRUD(2),ZRUD(2)
     1,RUDARM
     1,PRDARM,PRSPAN
C
      COMMON /PROPVR/ PDIA, PROPFM(3), PRPMS, PRPMP, PITCHS, PITCHP,
     1                PROPFM(6)
C
      COMMON /AIRVAR/ AIRFM(6)
C
      COMMON/HULVAR/HULLFM(6),HULCTK
C
      COMMON/BOYVAR/MSUBZ,MSUBTH,ZSUBZ,ZSUBTH,BUOYFM(6)
C
      COMMON/ADDVAR/ADMTRX(6,6,6),ADDFM(6),RTMTRX(6,6)
      COMMON/DOTCOF/XUDOT,YVDOT,YPDOT,YRDOT,ZWDOT,ZQDOT,KVDOT,KPDOT,
     1             KRDOT,MWDOT,MQDOT,NVDOT,NPDOT,NRDOT
C
      COMMON/CGMOVE/XC,YC,ZC
      LOGICAL PNT
C
      COMMON /FORMAT/ IR1,IR2,IR3,IR4,IR5,IP1,IP2,IP3,IP4,IP5,IP6,IP7,
     1               IP8,IP9,IP10,PNT(15)
C
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      COMMON /OPTION/ IFOF,IOPT(20)
C
      COMMON /STATIC/ TO,UO,VO,WO,PO,QO,RO,PHIO,THETAO,PSIO
C
      COMMON /CNTROL/ DT,DTMIN,TMAX,AE(15),EPS(15),NSTATE
C
C        DT           - STEP SIZE FOR CALLS TO KUTMER, SEC
C        DTMIN        - MINIMUM STEP SIZE TO BE USED BY KUTMER, SEC
C        TMAX         - SIMULATION STOP TIME
C        AE(1-15)     - ABSOLUTE INTEGRATION ERROR CRITERIA FOR STATE
C                       VECTOR, Y(1-15)
C        EPS(1-15)    - RELATIVE ERROR CRITERIA FOR Y(1-15)
C
      COMMON /MCONTL/ NCONT,IC1(10),IC2(10),IACT(10),JACT(10),CV1(10),
     *                CV2(10),CV3(10),CV4(10),CPIN1(16),CPIN2(16),
     *                COIN1(10),COIN2(10),COINT(10),RELAP(2),CHECK(2),
     *                RATE(12),KACT(12)
      COMMON /OUTY  / IFUP(5),IPRINT(5),JF ,  ,  ,IPRINT
C
      COMMON /HEADER/ TITLE(10)
      DATA CONV/3*1.,6*57.29577,5*1.,57.29577,1./
C
      IF(NCONT.EQ.0) RETURN
C     CONVERT CONTROL SURFACE POSITIONS TO PROPER UNITS. INITIALIZE
C     ARRAY CONT.
C
      CONT(1 ) = PPRMS
      CONT(2 ) = PPRMP
      CONT(3)=PITCHS
      CONT(4)=PITCHP
      CONT(5)=PRUDAS
      CONT(6)=PHLCAF
      CONT( 7)=RADIAN*RUDANG(1)
      CONT( 8)=RADIAN*RUDANG(2)
      CONT(9 ) =  FINANG(1)*RADIAN
      CONT(10) =  FINANG(2)*RADIAN
      CONT(11) =  FINANG(3)*RADIAN
      CONT(12) =  FINANG(4)*RADIAN
C
      DO 50 I=1,NCONT
       IF(IACT(I).NE.0) GO TO 50
         J1 = IC1(I)
         IF(J1.EQ.16) XV = T
          IF(J1.EQ.14) XV =SPEED  +CONV(J1)*CV4(I)
          IF(J1.EQ.15) XV =DRIFAN+CONV(J1)*CV4(I)
          IF(J1.LT.14) XV = Y(J1)*CONV(J1)*CV4(I)
C        CHECK TO SEE IF ACTION IS REQUIRED
         IF((XV-CV1(I)).LT.1.0E-05)GO TO 50
C
C         IF CURRENT VALUE IS EQUAL TO ORDERED VALUE, TAKE NO ACTION
C
          J2=IC2(I)
          XW = CV2(I)-CONT(J2)
          IF(ABS(XW).LT.0.00001) GO TO 50
C
C
C
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      IF(KACT(J2).EQ.0) GO TO 15
C      MULTIPLE COMMANDS
       WRITE(IP6,693) J2
693    FORMAT(41H MULTIPLE COMMANDS FOR CONTROLLED SURFACE,I4)
C
15     CONTINUE
C      ACTIVATE COMMAND
       IACT(I) = 1
       KACT(J2) = 1
C      COMPUTE CONSTANTS REQUIRED FOR LINEAR MODEL-INITIALIZATION
C
       A(I,1) = SIGN(CV3(I),XV)

       A(I,2) = -T*A(I,1)+CONT(J2)
       A(I,3) = XV/A(I,1) + T
       A(I,4) = T
      CONACT(I)=CONT(J2)
C
       WRITE(IP6,715)  T,CPIN1(J1),XV,CRIT2(J1),COIN1(J2),
     1  C?2(I),COIN2(J2),A(I,1),COIN3(J2),A(I,2),A(I,3)
715    FORMAT(3X,F9.3,2X,A10,F10.5,2X,A10,1X,A12,F15.5,2X,A8,2X,
     1       F10.5,1X,A4,2F12.5,4H SEC.  )
C
50    CONTINUE
C
C     COMPUTE NEW VALUES
C
      DO 100 I=1,NCONT
       IF(IACT(I).LE.0) GO TO 100
        J2 = ICP(I)
         CONT(J2) = A(I,1)*T + A(I,2)
        IF(T.GE.A(I,4)) GO TO 80
      CONT(J2)=CONACT(I)
80      CONTINUE
         IF(T.LT.A(I,3))  GO TO 100
C
C       CONTROL ACTION COMPLETED.
         IACT(I) =0
         IF(JACT(I).EQ.1) IACT(I)= -1
         KACT(J2) = 0
         CONT(J2) = CV2(I)
100   CONTINUE
      RRRMS=CONT(1)
      RRRMP=CONT(2)
      PITCHS=CONT(3)
      PITCHP=CONT(4)
      RRUDAS=CONT(5)
      RRUDAP=CONT(6)
      RUDANG(1)=CONT(7)/RADIAN
      RUDANG(2)=CONT(8)/RADIAN
      FINANG(1)=CONT( 9)/RADIAN
      FINANG(2)=CONT(10)/RADIAN
      FINANG(3)=CONT(11)/RADIAN
      FINANG(4)=CONT(12)/RADIAN
      RETURN
      END
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      SUBROUTINE DAUX (T,Y,F),RETURNS(1TAP)
      REAL LENGTH,MASS,IXX,IYY,IZZ,IXY,IXZ,IYZ,XFDOT,YFDOT,ZVECT,
     1      MDOT,T,TAPOT,UN  T,XFDOT,MUDOT,MOMO2,LENGTH
      COMMON /CRAFT / COEFICT, LENGTH, MASS   ,IXX,IXY,IXZ, IYY,IYZ, IZZ
C
      COMMON /CONST / RADIAN, RHOA, RHOAO, RHO , GRAVO,ETTOY
C
      COMMON /STATE / U,V,W,P,Q,R,PHI,THETA,PSI,XE,YE,ZE,S,SPEED,
     1                CHIFAN,COSPHI,COSTHE,COSPST,SINPHI,SINTHE,SINPST,
     2                TMTRX(3,3),TIME
C
      COMMON/FINVAR/XFIN(4),YFIN(4),ZFIN(4),SPAFIN(4),CLFIN(4),
     2CDFIN(4),FINANG(4),XFORCE(4),YFORCE(4),ZFORCE(4),ALIFT(4),
     3DRAG(4),FF(6)
     4,FINLIC(4)
C
      COMMON /HYDRO / LS(4),LT,HY(4,3217),FF(4,16),XC(4,20),IPOINT(4),
     .                UMAX,HYFORM(4),ICNT
C
C
      COMMON/RUDVAR/RUDANG(2),UDVEL(100),RALFA(100),AXRUD(100),YRUD(100),
     .              SKFUD(100),ARUD(100),RUDTIP,RUDAND(2),NUMUDV,NUMRUL,
     .                 RUDMSX,RUDRAD,RUDAR,RUDFEN,RUDFM(4)
     1,XRUD(2),YRUD(2),ZRUD(2)
     1,RUDARY
     1, RUDRY, RSFM
C
      COMMON /PROPVR/ PDIA, PROARY(3), PROPS, PROPD, PITCHS, PITCHP,
     1                PROPFM(6)
C
      COMMON /STIVAR/ STRFM(6)
C
      COMMON/HULVAR/HULLFM(6),HULRIK
C
      COMMON/TIYVAR/MSURZ,MSURTH,ZSURZ,ZSURTH,SURFM(6)
C
      COMMON/ADDMAS/AMTRX(6,6,6),ADDFM(6),STMTRX(6,6)
      COMMON/ STOOT /XUDOT,YVDOT,YRDOT,YPDOT,ZWDOT,ZQDOT,KVDOT,KPDOT,
     .              KRDOT,MWDOT,MQDOT,NVDOT,NPDOT,NRDOT
C
      COMMON/COMOVE/XC,YC,ZC
      LOGICAL PNT
C
      COMMON /PPRNT/ IR1,IR2,IR3,IR4,IR5,IP1,IP2,IP3,IP4,IP5,IP6,IP7,
     1               IP8,IP9,IP10,PNT(15)
C
      COMMON /OPTION/ IDOF,IOPTN(20)
C
      COMMON /STATEO/ TO,UO,VO,WO,PO,QO,RO,PHIO,THETAO,PSIO
C
      COMMON /INTGRL/ DT,DTMIN,TMAX,AE(15),EPS(15),NSTATE
C
C        DT           - STEP SIZE FOR CALLS TO KUTMER, ETC
C        DTMIN        - MINIMUM STEP SIZE TO BE USED BY KUTMER, ETC
C        TMAX         - SIMULATION STOP TIME
C        AE(1-15)     - ABSOLUTE INTEGRATION ERROR CRITERIA FOR STATE
C                       VECTOR, Y(1-15)
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C          EPS(1-15)      - RELATIVE ERROR CRITERIA FOR Y(1-15)
C
      COMMON /XCONTL/ NCONT,IC1(10),IC2(10),IACT(10),JACT(10),CV1(10),
     1                CV2(10),CV3(10),CV4(10),CRIN1(16),CRIN2(16),
     2                COIN1(12),COIN2(12),COIN3(12),RELAB(2),CHECK(2),
     3                RATE(12),KACT(12)
      COMMON /OUTX  / IBUG(5),IPRINT(5),JRA,NRUN,NPRINT
C
      COMMON /HEADER/ TITLE(10)
      DIMENSION Y(13),A(6,6),F(13)
C          F              - GENERALIZED FORCE VECTOR
C          A              - GENERALIZED MASS/INERTIA MATRIX
C     DEFINE LOCAL VARIABLES
      U     = Y(1 )
      V     = Y(2 )
      W     = Y(3 )
      P     = Y(4 )
      Q     = Y(5 )
      R     = Y(6 )
      PHI   = Y(7 )
      THETA= Y(8 )
      PSI   = Y(9 )
      XE    = Y(10)
      YE    = Y(11)
      ZE    = Y(12)
      S     = Y(13)
      TIME=T
C
C     COMPUTE SPEED AND OTHER REQUIRED VALUES
C
      U2    = U*U + V*V + W*W
      SPEED= SQRT(U2)
      DRIFAN = -ASIN(V/SPEED)
      COSPHI = COS(PHI)
      COSTHE = COS(THETA)
      COSPSI = COS(PSI)
      SINPHI = SIN(PHI)
      SINTHE = SIN(THETA)
      SINPSI = SIN(PSI)
C
C     COMPUTE FIXED TO BODY TRANSFORMATION MATRIX
C
      TMTRX(1,1)  = COSTHE*COSPSI
      TMTRX(1,2)  = COSTHE*SINPSI
      TMTRX(1,3)  =-SINTHE
C
      TMTRX(2,1)  =-COSPHI*SINPSI+ SINTHE*SINPHI*COSPSI
      TMTRX(2,2)  = COSPHI*COSPSI + SINTHE*SINPHI*SINPSI
      TMTRX(2,3)  = COSTHE*SINPHI
C
      TMTRX(3,1)  = SINPHI*SINPSI + SINTHE*COSPHI*COSPSI
      TMTRX(3,2)  =-SINPHI*COSPSI + SINTHE*COSPHI*SINPSI
      TMTRX(3,3)  = COSTHE*COSPHI
C
C     COMPUTE CONTROLLER ENVIRONMENTAL FACTORS SUCH AS WIND GUSTS,
C     COMPUTE PILOT ACTIONS. MAJOR LINK IS VIA COMMON
C
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C
      CALL CONTRL(T,Y)
C
C     COMPUTE TOTAL FIN FORCES AND MOMENTS.
C
      CALL FINFOR
C
C     COMPUTE TOTAL RUDDER FORCES AND MOMENTS.
C
      CALL RUDFOR
C
C     COMPUTE BARE HULL FORCES AND MOMENTS
C
      CALL HULFOR
C
C     COMPUTE AERODYNAMIC FORCES AND MOMENTS
C
      CALL AIRFOR
C
C     COMPUTE BUOYANCY FORCES AND MOMENTS
C
      CALL BOYFOR
C
C     COMPUTE PROPELLER FORCES AND MOMENTS
C
      CALL PROFOR
C
C     COMPUTE ACCELERATION AND ADDITIONAL RATE DEPENDENT FORCES AND MOME
C
      CALL ADDFOR
C
C     SUM TOTAL FORCES AND MOMENTS
C
      DO 1 I= 1, 6
        F(I) =FFM(I)+RUDFM(I)+HULLFM(I)+AIRFM(I)+BUOYFM(I)
     A           +PROPFM(I)   +   ADDFM(I)
1     CONTINUE
C
C
C ADD ON TERMS DUE TO CENTER OF GRAVITY NOT AT ORIGIN
      F(1)=F(1)              +MASS*(XC*(Q*Q+R*R)-YC*P*Q-ZC*P*R)
      F(2)=F(2)              +MASS*(YC*(R*R+P*P)-ZC*Q*R-XC*Q*P)
      F(3)=F(3)              +MASS*(ZC*(P*P+Q*Q)-XC*R*P-YC*R*Q)
      F(4)=F(4)              +MASS*(ZC*(U*R-W*P)+YC*(U*Q-V*P))
      F(5)=F(5)              +MASS*(XC*(V*P-U*Q)+ZC*(V*R-W*Q))
      F(6)=F(6)              +MASS*(YC*(W*Q-V*P)+XC*(W*P-U*R))
C     ADD ON ADDITIONAL TERMS ARISING FROM SPACE/BODY TRANSFORMATION
C
      F(1)=  F(1)+(V*R - W*Q)*MASS
      F(2)=  F(2)+(W*P - U*R)*MASS
      F(3)=  F(3)+(U*Q - V*P)*MASS
C
      F(4) =   (IYY-IZZ)*Q*R + IXZ*P*Q+ F(4)+ (Q*Q-R*R)*IYZ - IXY*P*R
      F(5) =   (IZZ-IXX)*R*P + IXY*Q*R+ F(5)+ (R*R-P*P)*IXZ - IYZ*Q*P
      F(6) =   (IXX-IYY)*P*Q + IYZ*R*P+ F(6)+ (P*P-Q*Q)*IXY - IXZ*R*Q
C
C       LOAD INERTIA/MASS MATRIX
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C
      DO 10 I=1,6
        DO 10 J=1,6
          A(I,J)= 0.0
10    CONTINUE
      A(1,1)=MASS-XUDOT
      A(1,5)=MASS*ZC
      A(1,6)=-MASS*YC
      A(2,2)=MASS-YVDOT
      A(2,4)=-MASS*ZC-YPDOT
      A(2,6)=-YRDOT+MASS*XC
      A(3,3)=MASS-ZWDOT
      A(3,4)=MASS*YC
      A(3,5)=-MASS*XC-ZQDOT
      A(4,2)=-MASS*ZC-KVDOT
      A(4,3)=MASS*YC
      A(4,4)=IXX-KPDOT
      A(4,5)=-IXY
      A(4,6)=-IXZ-KRDOT
      A(5,1)=MASS*ZC
      A(5,3)=-MASS*XC-MWDOT
      A(5,4)=-IXY
      A(5,5)=IYY-MQDOT
      A(5,6)=-IYZ
      A(6,1)=-MASS*YC
      A(6,2)=+MASS*XC-NVDOT
      A(6,4)=-IXZ-NPDOT
      A(6,5)=-IYZ
      A(6,6)=IZZ-NRDOT
      IF(IDOF.NE.6)GO TO 100
C     SOLVE FOR (DOT( VECTOR
C
      CALL LINQ(A,F,6,IERR)
      IF(IERR.NE.0) GO TO 1995
C
C     PHIDOT, THETADOT, PSIDOT, UE, VE,WE, SPEED
C
      F(7) = (Q*SINTHE*SINPHI +R*SINTHE*COSPHI + P*COSTHE)/COSTHE
      F(8) =  Q*COSPHI - R*SINPHI
      F(9) = (R*COSPHI + Q*SINPHI)/COSTHE
C
      DO 30 I=1,3
        SS = 0.0
        DO 29 J = 1,3
                SS = SS + TMTRX(J,I)*Y(J)
29      CONTINUE
        F(9+I) = SS
30    CONTINUE
C
      F(13) = SQRT(F(10)**2+F(11)**2+F(12)**2)
C
      GO TO 999
C
100   CONTINUE
C
C     DEGREES OF FREEDOM ARE LESS THAN 6
C
```

```
C      PITCH ANGLE FIXED.  THDOT= 0.0 IMPLIES 0=Q*COSPHI-R*SINPHI.  HENCE
C      COSPHI*QDOT-SINPHI*RDOT=PHIDOT*(Q*SINPHI+R*COSPHI).  PHIDOT IS
C      USED FOR CONVENIENCE. EQUIVALENT NON (DOT( EXPRESSION COULD BE
C      USED FOR PHIDOT.
C
       A(5,1)=0.0
       A(5,2)=0.0
       A(1,5)=0.0
       A(3,5)=0.0
       A(4,5)=0.0
       A(6,5)=0.0
       A(5,3)=0.0
       A(5,4)=0.0
       A(5,5)=COSPHI
       A(5,6)=-SINPHI
C      COMPUTE PHIDOT
       F(7) =(Q*SINTHE*SINPHI + R*SINTHE*COSPHI + P*COSTHE)/COSTHE
       F(5) = F(7)*(Q*SINPHI+R*COSPHI)
       IF(IDOF.LT.5) GO TO 300
       CALL LINQ(A,F,6,IERR)
       IF(IERR.NE.0) GO TO 1999
       F(8) = 0.
       F(9) = (R*COSPHI + Q*SINPHI)/COSTHE
       DO 130 I = 1,3
         SS = 0.0
         DO 129 J = 1,3
                   SS = SS + TMTRX(J,I)*Y(J)
129      CONTINUE
         F(9+I) = SS
130    CONTINUE
       F(13) =  SQRT(F(10)**2+F(11)**2+F(12)**2)
C
       GO TO 999
C
300    CONTINUE
C
       IF(IDOF.LT.4) GO TO 400
C
C      4 DOF  NO PITCH, NO HEAVE. IMPLIES THETA DOT=0.,WE=0.. WEDOT=0.0.
C      0=-U*SINTHE+V*COSTHE*SINPHI + W*COSTHE*COSPHI IMPLIES
C        UDOT*SINTHE-VDOT*COSTHE*SINPHI-WDOT*COSTHE*COSPHI =
C          PHIDOT*V*COSTHE*COSPHI-PHIDOT*W*COSTHE*SINPHI
C
       A(3,1)= SINTHE
       A(3,2)=-COSTHE*SINPHI
       A(3,3)=-COSTHE*COSPHI
       A(3,5)= 0.0
       A(3,4)=0.0
       A(3,6)=0.0
       A(4,3)=0.0
       A(5,3)=0.0
C
       F(3)= F(7)*COSTHE*(V*COSPHI-W*SINPHI)
C
       CALL LINQ(A,F,6,IERR)
       IF(IERR.NE.0) GO TO 1999
       F(8) = 0.0
```

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```
      F(9) = (R*COSPHI + Q*SINPHI)/COSTHE
      DO 330 I=1,3
        SS = 0.0
        DO 329 J=1,3
                SS = SS + TMTRX(J,I)*Y(J)
329     CONTINUE
        F(9+I) = SS
330   CONTINUE
      F(12) = 0.0
      F(13) = SQRT(F(10)**2+F(11)**2)
      GO TO 999
400   CONTINUE
      WRITE(6,601) IDOF
601   FORMAT(24H MODEL NOT AVAILABLE FOR,I4,19H DEGREES OF FREEDOM.//)
C
      STOP 6
CC
999   CONTINUE
      IF(PNT(10)) GO TO 1000
      RETURN
C     ***  INTERMEDIATE DEBUG OUTPUT     ***                  ***         **
C
 1000 WRITE(IP10,603) T,U,V,W,PHI,THETA,DRIFAN, (FFM(K),PUDFM(K),HULLFM
     1(K),AIRFM(K),BUOYFM(K),RDFM(K),PROPFM(K),K=1,6)
      PNT(10)=.FALSE.
      RETURN
1999  CONTINUE
C     NO INVERSE FOR MASS/INERTIA MATRIX.
      WRITE(IP6,600)
      WRITE(IP6,602)  (F(I),I=1,6),((A(I,J),J=1,6),I=1,6)
      WRITE(IP6,602)  IXX,IYY,IZZ,IXY,IXZ,IYZ,XUDOT,YVDOT,YPDOT,YRDOT,
     1                ZWDOT,ZQDOT,KVDOT,KPDOT,KRDOT,MWDOT,MQDOT,NVDOT,
     2                NPDOT,NRDOT
600   FORMAT(52H INVERSE OF MASS/INERTIA MATRIX DOES NOT EXIST. STOP/)
602   FORMAT(5H CALX,10E12.4)
  603 FORMAT(T3,4HTIME,T10,1HU,T16,1HV,T22,1HW,T27,3HPHI,T32,
     A5HTHETA,T39,4HBETA,T51,3HFIN,T59,6HRUDDER,T71,4HHULL,
     BT82,4HAERO,T92,8HBUOYANCY,T105,4HRATE,T113,10HPROPULSION,/,
     C1H ,F5.1,6F6.2,T45,1HX,7E11.4,/,T45,1HY,7E11.4,/,
     DT45,1HZ,7E11.4,/,T45,1HK,7E11.4,/,T45,1HM,7E11.4,/,T45,1HN,7E11.4
     C,/)
      STOP 5
      END
```

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```
      FUNCTION DRAAGG(V)
C     PERFORMS INTERPOLATION FOR DRAG FOR SWATH
      DIMENSION SPEED(25),EHP(25)
      DATA SPEED/0.,5.,6.,7.,8.,9.,10.,11.,12.,13.,14.,15.,16.,17.,18.,
     .           19.,20.,21.,22.,23.,24.,25.,26.,27.,28.      /
      DATA EHP/0.,100.,200.,400.,800.,1200.,1600.,2300.,3300.,4200.,
     1   5000.,5500.,6000.,6700.,7900.,9500.,12000.,15200.,18600.,
     1   21900.,24700.,27600.,30000.,32000.,33800./
      VMS=V
      V=VMS*1.944
      IF(V.LT.0.)GO TO 99
      DO 10 I=2,25
      IF(V.LE.SPEED(I))GO TO 15
   10 CONTINUE
   15 RATIO = (V-SPEED(I-1))/(SPEED(I)-SPEED(I-1))
      EHPV = (EHP(I)-EHP(I-1))*RATIO+EHP(I-1)
      DRAAGG = (EHPV*1450.1)/V
      V=VMS
      RETURN
   99 WRITE(6,20)V
   20 FORMAT(*   SPEED EXCEEDS RANGE  *,F10.4)
      RETURN
      END
```

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```
      SUBROUTINE EULER(T,DT,Y,NSTATE)
C
C     EULER INTEGRATION ROUTINE.
C
      DIMENSION Y(NSTATE),F(50)
C
C     COMPUTE RHS OF DIFFERENTIAL EQUATIONS.
C
      CALL DAUX(T,Y,F)
C
C     INTEGRATE FROM T TO  T + DT
C
      DO 1 I=1,NSTATE
        Y(I) = Y(I) + F(I)*DT
1     CONTINUE
C
C     UPDATE TIME
C
      T = T + DT
      RETURN
      END
```

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```
      SUBROUTINE FINFOR
C     PROGRAM TO COMPUTE FIN FORCES AND MOMENTS
      COMMON /CONST/ RADIAN,RHOA,RHOA2,RHOW,RHOW2,FTTOM
      COMMON /STATE/ U,V,W,P,Q,R,PHI,THETA,PSI,XE,YE,ZE,SPEED,S,DRIFAN,
     1COSPHI,COSTHE,COSPSI,SINPHI,SINTHE,SINPSI,TMTRX(3,3),TIME
      COMMON /FINVAR / XFIN(4),YFIN(4),ZFIN(4),ARAFIN(4),CLFIN(4),CDFIN
     1(4),FINANG(4),XFOREN(4),YFOREN(4),ZFOREN(4),ALIFT(4),DRAG(4),FFM
     1(6),FINAN0(2)
      DO 1 N=1,4
      CALL TOTVEL(U,V,W,P,Q,R,XFIN(N),YFIN(N),ZFIN(N),UTOTAL,VTOTAL,
     1WTOTAL)
      GAM=ATAN(WTOTAL/UTOTAL)
      ALFA=        GAM+FINANG(N)
      TRFOR=        GAM
      ALIFT(N)=RHOW2*ARAFIN(N)*      (UTOT    **2.+WTOTAL**2.)*CLFIN(N)*ALFA
      DRAG(N)=ABS(ALIFT(N))/7.
      XFOREN(N)=ALIFT(N)*SIN(TRFOR)-DRAG(N)*COS(TRFOR)
      ZFOREN(N)=-(ALIFT(N)*COS(TRFOR)+DRAG(N)*SIN(TRFOR))
    1 CONTINUE
      DO 2 N=1,6
    2 FFM(N)=0.
      DO 3 N=1,4
      FFM(1)=FFM(1)+XFOREN(N)
    3 FFM(3)=FFM(3)+ZFOREN(N)
      DO 4 N=1,4
      FFM(4)=FFM(4)+ZFOREN(N)*YFIN(N)-YFOREN(N)*ZFIN(N)
      FFM(5)=FFM(5)+XFOREN(N)*ZFIN(N)-ZFOREN(N)*XFIN(N)
    4 FFM(6)=FFM(6)+YFOREN(N)*XFIN(N)-XFOREN(N)*YFIN(N)
      RETURN
      END
```

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```
      SUBROUTINE HULFOR
      REAL LENGTH
      REAL MASS,IXX,IXY,IXZ,IYY,IYZ,IZZ
      COMMON /STATE / U,V,W,P,Q,R,PHI,THETA,PSI,XE,YE,ZE,SPEED,S,
     1                DRIFAN,COSPHI,COSTHE,COSPSI,SINPHI,SINTHE,SINPSI,
     2                TMTRX(3,3),TIME
      COMMON /CONST/ RADIAN, RHOA, RHOA2,RHOW,RHOW2,FTTOM
      COMMON/COMOVE/XC,YC,ZC
      COMMON/VARBLE/H(4),DUMMY(44)
      COMMON/HYDRO/LG(4),LZ,HY(4,3213),F(4,16),XG(4,20),IPOINT(4),
     1UMAX,HYDRFM(4),ICNT
      COMMON/CRAFT/SCFACT,LENGTH,MASS,IXX,IXY,IXZ,IYY,IYZ,IZZ
      COMMON/HULVAR/HULLFM(6),HULPIK
      DO 45 KU=2,6
   45 HULLFM(KU)=9999.
      H(1)=PHI*RADIAN
      H(2)=DRIFAN*RADIAN
      H(3)=R*LENGTH/U
      H(4)=U*1.944
      CALL HYDINT
      SSS=SQRT(U*U+V*V)
      FORCE=-DRAAGG(SSS)
      HULLFM(1)=FORCE*(1.+(.08*(HULPIK+ZE)))
      HULLFM(2)=HYDRFM(2)
      HULLFM(3)=(.5+.125*U)*RHOW2*LENGTH*LENGTH*.001*U*U
      HULLFM(4)=HYDRFM(3)
      HULLFM(5)=HULLFM(1)*(8.06-((HULPIK+ZE)/6.))
      HULLFM(6)=HYDRFM(4)
C
C     TERMS DUE TO CENTER OF GRAVITY NOT AT ORIGIN
      HULLFM(4)=HULLFM(4)+MASS*9.81*(YC*TMTRX(3,3)-ZC*TMTRX(2,3))
      HULLFM(5)=HULLFM(5)-MASS*9.81*(XC*TMTRX(3,3)-ZC*TMTRX(1,3))
      HULLFM(6)=HULLFM(6)+MASS*9.81*(XC*TMTRX(2,3)-YC*TMTRX(1,3))
      RETURN
      END
```

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```
      SUBROUTINE HYDINT
C        SUBROUTINE TO LINEARLY INTERPOLATE HYDRODYNAMIC FUNCTION
C        VALUES USING 16 STORED COEFFICIENTS.
      COMMON / VARBLE/  H(4),T,DT,DUMMY(42)
      COMMON / HYDRO/ LG(4),LT,HY(4,3213),C(4,16),XG(4,20),IPOINT(4),
     1      LMAX,HYDMR(4),ICNT
      COMMON/UNITY/ITUN(5),IPRINT(5),JPR,NRUN,NPRINT
      DIMENSION D(4)
C     WRITE(6,700)
C 700 FORMAT(* HYDINT--INTERPOLATION - - - -* )
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C        XG(I,J)=J-TH GRID POINT OF I-TH INDEPENDENT VARIABLE.
C        H= INDEPENDENT VARIABLE (NONDIMENSIONAL)
C        ROLL ANG=H(1), DRIFT VEL=H(2), YAW RATE=H(3), SPEED=H(4)
C        HY(I,J)=TABLE OF HYDRODYNAMIC FUNCTION VALUES
C              X(I=1), Y(I=2), N(I=3), K(I=4)
C        IPOINT=POINTER FOR GRID SET--TO COMPARE LAST ENTRY.
C        LG(I)=NO. OF GRID POINTS FOR I-TH VARIABLE.
C        LT=NO. OF POINTS FOR ZERO SPEED (ZERO VALUES NOT STORED)
C - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
C                    CHECK NONDIMENSIONAL SPEED.  IF GREATER THAN MAX
C        VALUE SET SPEED TO ALMOST MAX VALUE(TO AVOID NO DATA CELL).
      LG4=LG(4)
      IF( H(4) .GT. XG(4,LG4) )  H(4)=XG(4,LG4)-0.0000001
C - - - - - - - - - CHECK IF CURRENT VALUE OF INDEPENDENT VARIABLES (H)
C              ARE IN THE CURRENT CELL ( 4-DIMENSIONAL INTERVAL )
C              INDICATED BY VALUES OF IPOINT.  IF NOT FIND NEW CELL.
      ISW=0
      DO 20 I=1,4
      Z=H(I)
      M=IPOINT(I)
   10 IF( XG(I,M).GT.Z ) GO TO 15
      IF( XG(I,M+1).GT.Z) GO TO 20
C                             SEARCH UPWARD TO FIND NEW GRID POINT.
      ISW=1
      M=M+1
      IPOINT(I)=M
      IF(M.EQ.LG(I)) IPOINT(I)=M-1
      IF(M.EQ.LG(I)) GO TO 20
      GO TO 10
C                             SEARCH DOWNWARD TO FIND NEW GRID POINT.
   15 ISW=1
      M=M-1
      IPOINT(I)=M
      IF(M.EQ.0) IPOINT(I)=1
      IF(M.EQ.0) GO TO 20
      GO TO 10
   20 CONTINUE
C     WRITE(6,710) (IPOINT(I),I=1,4)
C 710 FORMAT(*   POINTER *,4I4)
C
C - - - - - - - - - IF ISW=1 NEW COEFFICIENTS MUST BE COMPUTED.
      IF( ISW.EQ.1 ) CALL HYDCOR
CC
C - - - - - - - - - -COMPUTE DISTANCE TO GRID POINT.
      DO 30 I=1,4
      M=IPOINT(I)
```

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```
   30   D(I)=H(I)-A(I,1)
C - - - - - - - - INTERPOLATION USING COEFFICIENTS.
        DO 50 I=1,4
        F0=A(I,1)
        F1=A(I,2)*D(1)+A(I,3)*D(2)+A(I,4)*D(3)+A(I,5)*D(4)
        F2=D(1)*( A(I,6)*D(2)+A(I,7)*D(3)+A(I,8)*D(4) )+
      1   D(2)*( A(I,9)*D(3)+A(I,10)*D(4) ) + A(I,11)*D(3)*D(4)
        F3=D(1)*D(2)*( A(I,12)*D(3)+A(I,13)*D(4) )+ D(3)*D(4)*
      1   ( A(I,14)*D(1)+A(I,15)*D(2) )
        F4=A(I,16)*D(1)*D(2)*D(3)*D(4)
        HYDYMF(I)=F0+F1+F2+F3+F4
C       WRITE(6,720) I,F0,F1,F2,F3,F4,HYDYMF(I)
C 720  FORMAT(/ * PARTS OF FORCE*,I2,5E14.5, *  TOTAL=*,E15.8 )
   50  CONTINUE
        RETURN
C
C - - - - - - - - - - NONDIMENSIONAL VALUES OUT OF BOUNDS---ERROR-----
  900  WRITE(6,750) I,( H(I),I=1,4)
        IBUG(1)=1
  750  FORMAT(///* VARIABLE NO. *, I4,* OUT OF BOUNDS IN HYDRO-*,
      1    *DYNAMIC INTERPOLATION*/
      2    3X,*ROLL ANG*11X,*DRIFT VEL*,10X,*YAW RATE*,15X,*SPEED*
      3  /4E20.8 // 5H STOP    )
C - - - - - - - - -   POINTER DESTROYED --REINITIALIZE AND SET
C - - - - - - - CORRESPONDING COEFFICIENTS FOR NEXT RUN.
        DO 210 I=1,4
  210  IPOINT(I)=LO(I)/2
        CALL HYDRAP
        RETURN
        END
```

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```
      SUBROUTINE HYDRAR
C           SUBROUTINE TO COMPUT LINEAR INTERPOLATION COEFFICIENTS
C           FOR 1 FUNCTION OF 4 INDEPENDENT VARIABLES. FUNCTION
C           VALUES ARE STORED IN A TABLE.
C
      COMMON / HYDRO/ LL1,LL2,LL3,LL4,L7, HY(4,3017),D(4,16),XG(4,20),
     1    IPOINT(4),UMAX,  XMAX(4),ICNT
      DIMENSION A(4,16), X(4)
C
C - - - - - - - - - -FUNCTION TO COMPUTE SUBSCRIPT
      INDX(IS,ID,IY,IS)= IS+LL1*( ID-1+LL2*( IY-1+LL3*(IS-1) ) )-L7
C                  COUNT CALLS TO THIS ROUTINE.
      ICNT=ICNT+1
C     WRITE(6,700)
C 700 FORMAT(/* HYDRAR - - - - - - -*)
C - - - - - - - - - - SET FUNCTION VALUES AT SURROUNDING GRID POINTS.
      M1=0
      DO 20 I4=1,2
      K1=IPOINT(1)+I3-1
      DO 20 I2=1,2
      K2=IPOINT(2)+I2-1
      DO 20 I1=1,2
      K3=IPOINT(3)+I1-1
      DO 20 I0=1,2
      K4=IPOINT(4)+I0-1
C     WRITE(6,705) K1,K2,K3,K4,XG(1,K1),XG(2,K2),XG(3,K3),XG(4,K4)
C 705 FORMAT( / * SUBSCRIPT= *,4I3,5X, *  ROLL VEL=*,F10.4,
C    1  *  DRIFT VEL=*,F10.4,  *  YAW R=*,F10.4,  *  SPEED=*,F10.4  )
      L1=INDX( K1, K2, K3, K4 )
      M1=M1+1
      DO 18 IV=1,4
      IF( L1.LE.0 )GO TO 15
      A(IV,M1)=HY(IV,L1)
      GO TO 18
C  - - - - - - - - VALUES FOR ZERO SPEED ARE SET TO ZERO-NOT STORED.
   15 A(IV,M1)=0.
   18 CONTINUE
C     WRITE(6,710) M1,L1, (A(I,M1),I=1,4)
C 710 FORMAT( * M1=*,I3, *  INDEX=*,I5, 5X, *  X=*,E15.5, *  Y=*,E15.5
C    2   *  N=*,E15.5,  *, K=* E15.5  )
   20 CONTINUE
CF
C - - - - - - - - - -COMPUTE DIFFERENCE BETWEEN GRID POINT COORDINATES.
      XG(4,LL4)=XG(4,LL4)/UMAX
      DO 30 I=1,4
      M=IPOINT(I)
      D(I)=XG(I,M+1)-XG(I,M)
   30 CONTINUE
      XG(4,LL4)=XG(4,LL4)*UMAX
C - - - - - - - - -COMPUTE 16 COEFFICIENTS FOR INTERPOLATION.
      DO 100 I=1,4
      Y=A(I,1)
      B(I,1)=Y
C                                   LINEAR TERMS
      B(I,2)=( A(I,3)-Y )/D(1)
      B(I,3)=( A(I,5)-Y )/D(2)
      B(I,4)=( A(I,3)-Y )/D(3)
```

```
      B(I,5)=( A(I,2)-Y )/D(4)
C                                 SECOND DEGREE TERMS.
      B(I,6)=( A(I,13)-A(I,9)-A(I,5)+Y )/( D(1)*D(2) )
      B(I,7)=( A(I,11)-A(I,9)-A(I,3)+Y )/( D(1)*D(3) )
      B(I,8)=( A(I,10)-A(I,9)-A(I,2)+Y )/( D(1)*D(4) )
      B(I,9)=( A(I,7)-A(I,5)-A(I,3)+Y )/( D(2)*D(3) )
      B(I,10)=( A(I,6)-A(I,5)-A(I,2)+Y )/( D(2)*D(4) )
      B(I,11)=( A(I,4)-A(I,3)-A(I,2)+Y )/( D(3)*D(4) )
C                                 CUBIC TERMS
      Y =A(I,15)-( A(I,13)+A(I,11)+A(I,7) )+( A(I,9)+A(I,5)+A(I,3) )-Y
      B(I,12)=Y/( D(1)*D(2)*D(3) )
      Y=A(I,14)-( A(I,13)+A(I,10)+A(I,6) )+(A(I,9)+A(I,5)+A(I,2) )-Y
      B(I,13)=Y/( D(1)*D(2)*D(4) )
      Y=A(I,12)-( A(I,11)+A(I,10)+A(I,4) )+( A(I,9)+A(I,3)+A(I,2) )-Y
      B(I,14)=Y/( D(1)*D(3)*D(4) )
      Y=A(I,8)-( A(I,7)+A(I,6)+A(I,4) )+( A(I,5)+A(I,3)+A(I,2))-Y
      B(I,15)=Y/( D(2)*D(3)*D(4) )
C                                 FOURTH DEGREE TERM
      Y=A(I,16)-( A(I,15)+A(I,14)+A(I,12)+A(I,8) ) +
     1   ( A(I,13)+A(I,11)+A(I,10)+A(I,7)+A(I,6)+A(I,4) ) -
     2   ( A(I,9)+A(I,5)+A(I,3)+A(I,2) )+Y
      B(I,16)=Y/( D(1)*D(2)*D(3)*D(4) )
C     WRITE(6,700) I,(B(I,J),J=1,16)
C 700 FORMAT(' COEFFICIENTS FOR INTERPOLATION-FUNCTION ',I4/
C    1   E20.5/4E20.5//E20.5/4E20.5/E20.5          )
  100 CONTINUE
      RETURN
      END
```

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```
      SUBROUTINE HYPRTT
      COMMON/HYDRO/LG(4),LT,HY(4,3013),F(4,16),XG(4,20),I
     1HMAX,HYTHER(4),ICNT
      WRITE(6,9999)
 9999 FORMAT(1H1,2X,10HROLL ANGLE,5X,11HDRIFT ANGLE,5X,8HYAW RATE,5X,
     18HSPEED,7X,7HY FORCE,9X,8HK MOMENT,9X,8HN MOMENT,/,1H ,5X,3HDEG,
     2[illegible]
     3[illegible]
      ISSS=LG(4)
      IYYY=LG(3)
      IDDD=LG(2)
      IRRR=LG(1)
      N=0
      DO 9995  ISS=1,ISSS
      DO 9996  IYY=1,IYYY
      DO 9997  IDD=1,IDDD
      DO 9998  IRR=1,IRRR
      N=N+1
      IF(N.GE.47) WRITE(6,9999)
      IF(N.GE.47) N=1
      NX= ((((IYY-1+(LG(3)*(ISS-1)))*LG(1))+IDD-1)*LG(3))+IRR
      WRITE(6,9990)XG(1,IRR),XG(2,IDD),XG(3,IYY),XG(4,ISS),HY(2,NX),
     1 HY(3,NX),HY(4,NX)
 9990 FORMAT(1H ,4X,F5.2,10X,F5.2,9X,F5.2,7X,F5.2,5X,3(E12.6,4X))
 9998 CONTINUE
 9997 CONTINUE
 9996 CONTINUE
 9995 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE INPUT(Y,TIMEO)
C
C     THIS ROUTINE READS ALL INPUT DATA
C
C
      REAL LENGTH,MASS,IXY,IXX,IXZ,IYY,IYZ,IZZ,KPDOT,KRDOT,KVDOT,
     1     MQDOT,MUDOT,MWDOT,NPDOT,NVDOT,MSUBZ,MSUBTH
      COMMON /CRAFT / SCFACT, LENGTH, MASS   ,IXY,IXX,IXZ, IYY,IYZ, IZZ
C
      COMMON /CONST / RADIAN, RHO , RHOAD, RHOW, RHOW2,FTTOM
C
      COMMON /STATE / U,V,W,P,Q,R,PHI,THETA,PSI,XE,YE,ZE,S,SPEED,
     1                DRIFAN,COSPHI,COSTHE,COSPSI,SINPHI,SINTHE,SINPSI,
     2                TMTRX(3,3),TIME
C
      COMMON/FINVAR/XFIN(4),YFIN(4),ZFIN(4),ARAFIN(4),CLFIN(4),
     2DEFIN(4),FINANG(4),XFORCE(4),YFORCE(4),ZFORCE(4),ALIFT(4),
     3DRAG(4),FFM(6)
     4,FINANG(4)
C
      COMMON /HYDRO / IS(4),LT,HY(4,3013),FF(6,16),YA(4,20),IPOINT(4),
     1                UMAX,HYDFEM(4),ICNT
C
C
      COMMON/RUDVAR/RUDANG(2),HUVEL(10),RALFA(10),AXRUD(100),AYRUD(100),
     1              AKRUD(100),ANRUD(100),ARATIO,RUDANG(2),NUMUUV,NUMRAL,
     1                RUDRON,RRLOSS,FTUDAP,RRCCFM,RUDFM(6)
     1,XRUD(2),YRUD(2),ZRUD(2)
     1,RUDARY
     1,SRDARY,RSRAN
C
      COMMON /PROPVR/ PDIA, PROPRM(3), PRPMS, IPRXP, PITCHS, PITCHP,
     1                PROPFM(6)
C
      COMMON /AIRVAR/ AIRFM(6)
C
      COMMON/HULVAR/HULLFM(6),HULRIK
C
      COMMON/BOYVAR/MSUBZ,MSUBTH,ZSUBZ,ZSUBTH,BUOYFM(6)
C
      COMMON/ADDVAR/ADMTRX(6,6,6),ADDFM(6),RTMTRX(6,6)
      COMMON/DOTCOF/XUDOT,YVDOT,YRDOT,YRDOT,ZWDOT,ZQDOT,KVDOT,KPDOT,
     1              KRDOT,MWDOT,MQDOT,NVDOT,NPDOT,NRDOT
C
      COMMON/CGMOVE/XC,YC,ZC
      LOGICAL PNT
C
      COMMON /PRPRNT/ IR1,IR2,IR3,IR4,IR5,IP1,IP2,IP3,IP4,IP5,IP6,IP7,
     .                IP8,IP9,IP10,PNT(15)
C
      COMMON /OPTION/ IPGE,IOPT(20)
C
      COMMON /STATEO/ TO,UO,VO,WO,PO,QO,RO,PHIO,THETAO,PSIO
C
      COMMON /INTGRL/ DT,TMIN,TMAX,AT(15),EPS(15),NSTATE
C
C     DT               - STEP SIZE FOR CALLS TO KUTMER, SEC
```

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C          DTMIN           - MINIMUM STEP SIZE TO BE USED BY KUTMER, SEC
C          TMAX            - SIMULATION STOP TIME
C          AE(1-15)        - ABSOLUTE INTEGRATION ERROR CRITERIA FOR STATE
C                            VECTOR, Y(1-15)
C          EPS(1-15)       - RELATIVE ERROR CRITERIA FOR Y(1-15)
C
      COMMON /XCONTL/ ICONT,IC1(10),IC2(10),IACT(10),JACT(10),CV1(10),
     1                CV2(10),CV3(10),CV4(10),CRIT1(14),CRIT2(14),
     2                CRIT1(10),CRIT2(10),CRIT(10),RELAR(2),CHECK(2),
     3                RATE(10),KACT(10)
      COMMON /OUTY  / ISUB(5),IPRINT(5),JRN,IRUN,NPRINT
C
      COMMON /HEADER/ TITLE(10)
C
      DIMENSION Y(20)
C
      DATA PRPXPO/200./,PRPMPO/200./, PTCHPO/0./, PTCHPO/0./,
     A        FINANO/4*0.0/,
     B              PRUDPO/0./,RUDRPO/0./,RUDANO/2*0.0/
C
      NAMELIST /SWATHR/ TI,UO,VO,RO,QO,PO,PHIO,THETAO,PSIO,
     .                      XO,YO,ZO,
     1                  SCFACT,LENGTH,MASS,IXX,IYY,IZZ,IXY,IXZ,IYZ,
     2                  PDIA,PROARM,PRPMSO,PRPMPO,PTCHSO,PTCHPO,
     3                  FINANO,ARAFIN,XFIN,YFIN,ZFIN,RUDANO,ARATIO,
     4                  BRUDSO,BRUDPO,
     .              BFSPAN,FRDARM,
     4    XPROT,YPROT,ZPROT,XPROT,YPROT,XPROT,KPROT,XPROT,KPROT,YUPROT,
     5    ZPROT,ZPROT,MPROT,MPROT,CLFIN,ZSUBZ,ZSUBTH,MSUBZ,MSUBTH,
     6    NUMBAL,NUMQUV,
     6 NULRTK,
     7                  IDOF,ENT,DT,DTMIN,TMAX,AE,EPS,IRUN
     8                   ,IOPT,TITLE,NPRINT
     9              ,UUVEL,BALEN,AXRUD,AYRUD,AKRUD,ANRUD
     A              ,XRUD,YRUD,ZRUD,RUDARM
C
      READ(IRE,800)(TITLE(I),I=1,10)
800   FORMAT(10A8)
400   FORMAT(21H1O,4TH SIMULATION RUN, I4,10X,10A8//)
      READ(IRE,SWATHR)
      WRITE(IRE,SWATHR)
C
C     CONVERT INITIAL CONDITIONS TO PROPER INTERNAL UNITS
C
      U      = UO*1.689*FTTOM
      V      = VO*1.689*FTTOM
      W      = WO*1.689*FTTOM
C
      P      =  PO/RADIAN
      Q      =  QO/RADIAN
      R      =  RO/RADIAN
C
      TIME = TI
      TIMEE=TIME
      SPEED = SQRT(U*U+V*V+W*W)
      D =0.0
C
```

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```
      PREFM=LT+1.5HP+FTTCM
      PRIFAM=0.0
      XE=0.0
      YE=0.0
      ZE=0.0
      S =0.0
      PHI   =   PHIO/RADIAN
      THETA=   THETAO/RADIAN
      PSI   =   PSIO/RADIAN
      PRPMS   = PRPMSO
      PRPMP   = PRPMPO
      PITCHS=PTCHSO
      PITCHP=PTCHPO
      DO 8240 IPP=1,4
 8240 FINANG(IPP) = FINANO(IPP)/RADIAN
      RUDANG(1)=RUDANO(1)/RADIAN
      RUDANG(2)=RUDANO(2)/RADIAN
      RRUDAS=RRUDSO
      RRUDAP=RRUDPO
C
      Y(1)=U
      Y(2)=V
      Y(3)=W
      Y(4)=P
      Y(5)=Q
      Y(6)=R
      Y(7)=PHI
      Y(8)=THETA
      Y(9)=PSI
      Y(10)=XE
      Y(11)=YE
      Y(12)=ZE
      Y(13)=S
C     INITIALIZE LINE COUNTER FOR OUTPUT PROGRAM
      ICA      = 0
C     ADJUST TMAX TO ASSURE PROPER INEQUALITY CHECK IN SUBSEQUENT CODE
C
      TMAX = TMAX-DT/100.
C
C     ***                   XCONTL  INPUT                     ***
C
       READ(IRE,510) NCONT
 510   FORMAT(I10,F10.2,I10,2F10.2,I10)
       IF(NCONT.LT.0)GO TO 900
       IF(NCONT.EQ.0) GO TO 130
C        READ IN PILOT ACTION COMMAND DATA
C
         WRITE(IR6,602) NCONT
 602     FORMAT(/,16H THERE ARE TO BE,I4,9H  ACTIONS/)
C
         WRITE(IR6,603)
 603     FORMAT(4X,19H CONTROL CONDITION,20X,14HCOMMAND CHANGE,4X,2HTO,
        *17X,4HRATE,/)
C
C        READ COMMANDS
C
         DO 102 I=1,NCONT
```

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```
      ??EFF=L)*1.AHS+RTTC?
      ?RIFAN=?.0
      XF=?.0
      YF=?.0
      ZF=?.0
      ? =?.0
      PHI  =  PHIC/RADIAN
      THETA=  THTAC/RADIAN
      PSI  =  PSIC/RADIAN
      ?RPMS  = ?RPMSJ
      ?RPMP  = RRPMP?
      PITCHS=PTCHSC
      PITCHP=PTCHPC
      DO 9240 IPP=1,4
9240  FINANG(IPP) = FINANG(IPP)/RADIAN
      RUDANG(1)=RUDANG(1)/RADIAN
      RUDANG(2)=RUDANG(2)/RADIAN
      ?RUDAS=?RUDS?
      ?RUDAP=?RUDP?
C
      Y(1)=U
      Y(2)=V
      Y(3)=W
      Y(4)=P
      Y(5)=Q
      Y(6)=R
      Y(7)=PHI
      Y(8)=THETA
      Y(9)=PSI
      Y(10)=XF
      Y(11)=YF
      Y(12)=ZF
      Y(13)=S
C     INITIALIZE LINE COUNTER FOR OUTPUT PROGRAM
      IFA     = 0
C     ADJUST TMAX TO ASSURE PROPER INEQUALITY CHECK IN SUBSEQUENT CODE
C
      TMAX = TMAX-DT/100.
C
C     ***                 XCONTL  INPUT                  ***
C
        READ(IR5,510) NCONT
510     FORMAT(I10,F10.2,I10,2F10.2,I10)
        IF(NCONT.LT.0)GO TO 900
        IF(NCONT.EQ.0) GO TO 130
C         READ IN PILOT ACTION COMMAND DATA
C
          WRITE(IR6,602) NCONT
602       FORMAT(/,16H THERE ARE TO BE,I4,9H  ACTIONS/)
C
          WRITE(IR6,603)
603       FORMAT(4X,18H CONTROL CONDITION,20X,14HCOMMAND CHANGE,4X,2HTO,
     .    17X,4HRATE,/)
C
C         READ COMMANDS
C
          DO 102 I=1,NCONT
```

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```
      READ(IR5,510) J1,CV1(I),J2,CV2(I),CV3(I),JACT(I)
      CV4(I)=SIGN(1.,FLOAT(J1))
      IF(J1.LT.0) M=2
      IF(J1.GT.0) M=1
      IF(JACT(I).LE.0) N=2
      IF(JACT(I).GT.0) N=1
      IF(J1.LT.0) J1=-J1
      IF(J1.EQ.14) JACT(I)=1
      IF(J1.EQ.16) N=1

      IC1(I) = J1
      IC2(I) = J2
C
   IF(J1.LE.0.OR.J1.GE.17.OR.J2.LE.0.OR.J2.GE.14) GO TO 991
C
C     SET ACTIVITY INDICATOR TO ZERO
      IACT(I) = 0
C     USE DEFAULT RATES IF COMMANDED RATE IS ZERO
      IF(CV3(I).LT.0.001) CV3(I)=RATE(J2)
C
C     PRINT OUT COMMANDS
C
      WRITE(IR6,600) CRIT1(J1),RELAT(M),CV1(I),CRIT2(J1),
     *LIM1(J2),CV2(I),CRIT2(J2),CV3(I),CRIT3(J2),CHECK(N)
600   FORMAT(4X,A10,F6.3,10,F10.2,2X,2A10,1X,F10.2,2X,A5,2X,F10.2,
     1  2X,A7,3X,A10)
C
C     CONVERT RATES TO PROPER SIGNS
C
      CV1(I)=CV1(I)*CV4(I)
C
100   CONTINUE
C     INIT KACT TO ZERO
C
      DO 103 I=1,12
103   KACT(I) = 0
C
130   CONTINUE
C
C
C
C
C     **        **    READ HYDRO DATA     **       **
      DO 8680 LKJ=1,6
      DO 8680 LKM=1,6
8680  DTMTRX(LKJ,LKM)=0.0
      DO 8681 LOOP1=1,36
      READ(IR5,8682) IN,JN,COEFF
8682  FORMAT(2I3,F10.4)
      IF(IN.LT.0) GO TO 8700
      DTMTRX(IN,JN)=COEFF
8681  CONTINUE
8700  CONTINUE
      DO 8950 IIK=1,6
      DO 8950 IIL=1,6
      DO 8950 IIM=1,6
8950  D2MTRX(IIK,IIL,IIM)=0.0
      DO 8951 ICATT=1,216
      READ(IR5,8952) IN,JN,KN,COEFF
```

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```
8050 FORMAT(3I2,E10.4)
     IF(IU.LT.0) GO TO 8053
     ADMTRX(IU,JU,KU)=COEF
8051 CONTINUE
 853 CONTINUE
     DO 8043 I=1,4
       DO 8043 J=1,[illegible]
         HY(I,J) = 0.0
8043 CONTINUE
     DO 8044 ITAPE=1,3
     REWIND ITAPE
     DO 8045 KL = 1,4
8045 READ(ITAPE) L6(KL)
     DO 8046 IK=1,4
     KX=L6(IK)
     IPOINT(IK)=KX/2
8046 READ(ITAPE)(Y6(IK,J),J=1,KX)
     KY=L6(1)*L6(2)*L6(3)*L6(4)
     LZ=0
     K=ITAPE+1
     READ(ITAPE)(HY(K,J),J=1,KY)
     DO 8047 IM=1,KY
     DRL2=RHOV2*LENGTH*LENGTH
     DRL3=DRL2*LENGTH
     MN=KY/L6(4)
     MM=(IM+MN-1)/MN
     DRL2U2=DRL2*Y6(4,MM)*Y6(4,MM)*.26461
     DRL3U2=DRL2U2*LENGTH
     HY(1,IM)=0.0
     IF(ITAPE.LE.1) GO TO 8048
     HY(K,IM)=HY(K,IM)*DRL3U2
     GO TO 8047
8048 HY(K,IM)=HY(K,IM)*DRL2U2
8047 CONTINUE
8044 CONTINUE
     IF (EOF(2)) GO TO 8312
     RETURN
8312 CALL HYPITT
     RETURN
C
 600 CONTINUE
C    NCONT INCORRECT
     WRITE(IPA,601) NCONT
 601 FORMAT(///,46H INVALID NUMBER OF PILOT ACTIONS READ. NCONT =,I4,
    1       9H  CHECK INPUT DATA CARDS.//)
     STOP
 [illegible]1 CONTINUE
     WRITE(IPA,604) I
 604 FORMAT(///,49H ERROR ON INPUT CARDS FOR PILOT COMMANDS. CARD NO.,I4)
     STOP
     END
```

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```
      SUBROUTINE KUTMER(NO,T,H,Y0,ERSE,A,HCX,FIRST)
      DIMENSION      Y0(20),Y1(20),Y2(20),F0(20),F1(20),F2(20)
      DIMENSION      ERSE(20),A(20)
      COMMON/OUTY/IBUG(5),IPRINT(5),JPB,NRUN,NPRINT
      DATA NAM1,NAM2 /2HY1,2HY2/
C
C   ALGORITHM 218 FROM DEC 1963 COMMUNICATION OF ACM.
C              ERROR INFORMATION AND STEP SIZE WRITTEN TO TAPE 2.
C      NO= NUMBER OF EQUATIONS, NO. OF COMPONENTS OF Y0
C      T= INDEPENDENT VARIABLE
C      H=INCREMENT FOR WHICH SOLN IS TO BE RETURNED  + OR-
C      Y0 IS THE VECTOR OF DEPENDENT VARIABLES.  ENTER WITH INITIAL
C         VALUES AT T AND RETURNS WITH VALUES AT T+H
C      ERSE=RELATIVE ERROR CRITERION FOR COMPONENTS OF Y0 .GT. ABS(A)
C      A=ABSOLUTE ERROR CRITERIA FOR COMPONENTS OF Y0 .LT. ABS(A)
C NOTE-- ERSE AND A MUST BE SPECIFIED FOR EACH COMPONENT OF THE SYSTEM
C      HCX = THE SMALLEST STEP SIZE USED IN THE INTEGRATION
C      DAUX(T,Y,F) RETURNS THE VECTOR F(T,Y)
C      FIRST  --  SHOULD BE =0. WHEN (1) KUTMER IS ENTERED FOR THE FIRST
C         TIME OR (2) ENTERED WITH A CHANGED H.
C       FIRST  SHOULD BE = 1.0 WHEN ENTERED WITH THE SAME H TO
C         CONTINUE INTEGRATION IN A SEQUENCE .
C       FIRST  WILL =2.0 WHEN THE ERROR CRITERIA CANNOT BE MEET AND
C         STEP SIZE IS REDUCED TO H/128.
C
      IF(Y0(1).LT.0.) FIRST=2.
      IF(Y0(1).LT.0.) GO TO 300
      IF(FIRST)20,10,20
C - - - - - - - - - -FIRST ENTRY
   10 HC=H
      IPLOC=1
      FIRST=1.
C - - - - - - - - - -OTHER ENTRY
   20 LOC=0
        HCX=HC
      IF(HC.NE.0.) GO TO 30
      WRITE(6,800)
  800 FORMAT(5X,*KUTMER ENTERED WITH ZERO INTEGRATION INTERVAL*  )
      FIRST=2.
      RETURN
C - - - - - - - - - - -  5 CALLS TO DAUX
C
   30 CALL DAUX(T,Y0,F0),RETURNS(300)
      IPRINT(1)=0
   33 DO 40 I=1,NO
   40 Y1(I)   =Y0(I)   +(HC/3.)*F0(I)
C
      CALL DAUX(T+HC/3., Y1,F1),RETURNS(300)
      DO 50 I=1,NO
   50 Y1(I)   =Y0(I)   +(HC/6.)*F0(I)+(HC/6.)*F1(I)
C
      CALL DAUX(T+HC/3., Y1,F1),RETURNS(300)
      DO 60 I=1,NO
   60 Y1(I)   =Y0(I)   +HC/8.*F0(I)+.375*HC*F1(I)
C
      CALL DAUX(T+HC/2., Y1,F2),RETURNS(300)
      DO 70 I=1,NO
```

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   70 Y1(I)    =Y0(I    )+HC/2.*F0(I)-1.5*HC*F1(I)+2.*HC*F2(I)
C
      CALL DAMN( T+HC,Y1,F3),RETURNS(300)
      DO 80 I=1,ND
   80 Y2(I)=Y0(I)   +HC/6.*F0(I)+( 2./3. )*HC*F2(I)+(HC/6.)*F1(I)
      INC=0
CB- - - - - - - - -CHECK ERROR CRITERIA
      DO 110 I=1,ND
      ZZZ=ABS(Y1(I))-A(I)
       IF(ZZZ) 95,97,97
C                                   ABSOLUTE ERROR
   95 ERROR=ABS(.2*(Y1(I)   -Y2(I)))
       IF( ERROR-A(I) )100,100,90
C                                   RELATIVE ERROR
   97 ERROR=ABS(.2-.2*Y2(I)/Y1(I)   )
       IF( ERROR-ERSE(I) )100,100,90
C - - - - - - - - - -SINCE ERROR.GT.ERROR CRITERIA CHECK IF HC.GT.H/128.
C - - - - - - - - - -IF YES THEN HALVE INTERVAL. OTHERWISE STOP.
   90 X= 128.*ABS(HC)-ABS(H)
       IF(X) 91,95,95
C                                   ERROR TOO LARGE.
   91 WRITE(6,92)I,T,ERROR,HC
   92 FORMAT(/18H FOR EQUATION NO. I2,27H. THE RELATIVE ERROR AT T = ,
     1      E15.8, 4H IS , E15.8 ,* STEP SIZE= *,E15.8 )
       FIRST = 0.
      RETURN
C                                   HALVE INTERVAL.
   95 HC=HC/2.
      IPLOC=2 *IPLOC
      LOC=2 *LOC
       HCY=HC
      WRITE(11,710) T,I,ERROR,HC
  710 FORMAT(/* TIME=*,F10.3,5X*HALVE INTERVAL.  EQUATION *,I3,
     *     * HAS ERROR=*,E10.8 ,6X,* STEP SIZE NOW = *,E15.8 )
      WRITE(11,720) NAM2,(Y2(J),J=1,ND)
      WRITE(11,720) NAM1,(Y1(J),J=1,ND)
  720 FORMAT( 2X,A8 / 3(10E13.5 /) )
      GO TO 70
C - - - - - - - - - -TEST IF INTERVAL LENGTH CAN BE DOUBLED.
  100 IF( ERROR*64.-ERSE(I) )110,110,101
  101 INC=1
  110 CONTINUE
CF- - - - - - - - -UPDATE T AND SOLUTION.
  111 T=T+HC
      DO 112 I=1,ND
  112 Y0(I)   =Y2(I)
C - - - - - - - - - - SET SOLUTION ON NEXT INTERVAL
      LOC=LOC+1
       IF(LOC-IPLOC)120,210,210
  120 IF(INC)210,130,210
  130 IF(LOC-(LOC/2)*2)210,140,210
  140 IF(IPLOC-1)210,210,200
C - - - - - - - - -DOUBLE INTERVAL LENGTH.
  200 HC=2.*HC
      LOC=LOC/2
      IPLOC=IPLOC/2
  210 IF(IPLOC-LOC)30,329,70
  329 RETURN
      END
```

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```
      SUBROUTINE LINC(A,B,N,KS)
C
C     SOLVES FOR X WHERE AX = B.
C     N - NUMBER OF EQUATIONS, DIMENSION OF A.
C     KS - ERROR CODE. 0 - NORMAL, 1 - SINGULAR MATRIX.
      DIMENSION A(1),B(1)
      TOL = 0.0
      KS = 0
      JJ = -N
      DO 65 J = 1,N
      JY = J+1
      JJ = JJ+N+1
      BIGA = 0.0
      IT = JJ-J
      DO 30 I = J,N
      IJ = IT +I
      IF(ABS(BIGA)-ABS(A(IJ))) 20,30,30
20    BIGA=A(IJ)
      IMAX = I
30    CONTINUE
      IF(ABS(BIGA) -TOL) 35,35,40
35    KS = 1
      RETURN
40    I1 = J+N*(J-2)
      IT = IMAX-J
      DO 50 K = J,N
      I1 = I1+N
      I2 = I1+IT
      SAVE = A(I1)
      A(I1) = A(I2)
      A(I2) = SAVE
50    A(I1) = A(I1)/BIGA
      SAVE = B(IMAX)
      B(IMAX) = B(J)
      B(J) = SAVE/BIGA
      IF(J-N) 55,70,55
55    IQS = N*(J-1)
      DO 65 IX = JY,N
      IXJ = IQS + IX
      IT = J-IX
      DO 60 JX = JY,N
      IXJX = N*(JX-1)+IX
      JJX = IXJX+IT
60    A(IXJX) = A(IXJX)-(A(IXJ)*A(JJX))
65    B(IX) = B(IX) -(B(J)*A(IXJ))
70    NY = N-1
      IT = N*N
      DO 80 J = 1,NY
      IA = IT-J
      IB = N-J
      IC = N
      DO 80 K=1,J
      B(IB) = B(IB) - A(IA)*B(IC)
      IA = IA-N
80    IC = IC-1
      RETURN
      END
```

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```
      SUBROUTINE NGHBR1 (V,ARG,II,N,IER,RATIO)
C---------------
C     NGHBR1 FINDS THE NEAREST NEIGHBOR .LE. TO ARG IN ARRAY V
C                V     - VARIABLE ARRAYS
C                ARG    - SEARCH ARGUMENT
C                II    - LOCATION S.T. V(II).LE.ARG.LT.V(II+1)
C                N     - NUMBER OF POINTS IN V
C                IER    - 0 IN RANGE, IF NOT OUT OF RANGE
C                RATIO    - (ARG-V(II))/(V(II+1)-V(II))
C------------------
      DIMENSION V(1)
      I=II
      IER = 0
      IO = 6
    1 CONTINUE
      IF(ARG.GE.V(I))GO TO 2
      I=I -1
      IF(I.GE.1)GO TO 1
      IER=1
      I=1
      GO TO 4
    2 IF(I+1 .GT.N) GO TO 3
      IF(ARG.LE.V(I+1))GO TO 4
      I= I+1
      GO TO 2
    3 I = N-1
      IER=1
    4 II = I
      RATIO = (ARG-V(I))/(V(I+1)-V(I))
      IF(IER.NE.1) RETURN
      WRITE(IO,600) II,N,V(I),V(I+1),ARG,RATIO
  600 FORMAT(*  OUT OF RANGE IN NGHBR1. II= *,I4,* N= *,I4,* V(I)= *,
     . F10.3,* V(I+1)= *,F10.3,* ARG= *,F10.3,* RATIO = *,F10.3,
     . /,*    ERROR    *)
      RETURN
      END
```

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```
      SUBROUTINE OUTPUT(IPRT)
C
C     THIS ROUTINE PRINTS FIVE PAGES OF OUTPUT
C       PAGE1  T,SPEED,U,V,P,R,PHI,DRIFT,HEADING,XE,YE,DISTANCE
C       PAGE2  T,SPEED,W,Q,THETA,ZE
C       PAGE3  T,SPEED,PITCHS,PITCHP,RPMS,RPMP,PROPFM(1-6)
C       PAGE4  T,SPEED,RRUDAS,RRUDAP,RUDAS,RUDAP,RUDFM(1-6)
C       PAGE5  T,SPEED,FBDANG,FBDANG,FSDANG,FSDANG,FFM(1-6)
C
      DIMENSION PAGE(4,40,14),FACT1(17)
      REAL LENGTH,MASS,IXX,IXY,IXZ,IYY,IYZ,IZZ,KPDOT,KRDOT,KVDOT,
     1     MPDOT,MUDOT,NPDOT,NRDOT,NVDOT,MSURZ,MSURTH
      COMMON /CRAFT / SCFACT, LENGTH, MASS   ,IXX,IXY,IXZ, IYY,IYZ, IZZ
C
      COMMON /CONST / RADIAN, RHOA, RHOA2, RHOW, RHOW2,FTTOM
C
      COMMON /STATE / U,V,W,P,Q,R,PHI,THETA,PSI,XE,YE,ZE,S,SPEED,
     1               DRIFAN,COSPHI,COSTHE,COSPSI,SINPHI,SINTHE,SINPSI,
     1               TMTRX(3,3),TIME
C
      COMMON/FINVAR/XFIN(4),YFIN(4),ZFIN(4),ARFIN(4),CLFIN(4),
     1DRFIN(4),FINANG(4),XFORFM(4),YFORFM(4),ZFORFM(4),ALIFT(4),
     2DRAG(4),FF(4)
     4,FINANG(4)
C
      COMMON /HYDRO / L6(4),L7,HY(4,3213),FF(4,16),XX(4,20),IPOINT(4),
     1               UMAX,HYDFM(4),ICNT
C
C
      COMMON/RUDVAR/RUDANG(2),UUVEL(10),RALFA(10),AXRUD(100),AYRUD(100),
     1              AKRUD(100),AMRUD(100),ARATIO,RUDANG(2),NUMUUV,NUMRAL,
     1              RUDRSN,RRUDAS,RRUDAP,RRSPAN,RUDFM(6)
     1,XRUD(2),YRUD(2),ZRUD(2)
     1,RUDARM
     1,RRDARM,RRSPAN
C
      COMMON /PROPVR/ PDIA, PRDARM(3), RRPMS, RRPMP, PITCHS, PITCHP,
     1               PROPFM(6)
C
      COMMON /AIRVAR/ AIRFM(6)
C
      COMMON/HULVAR/HULLFM(6),HULRIK
C
      COMMON/BCYVAR/MSURZ,MSURTH,ZSURZ,ZSURTH,BUCYFM(6)
C
      COMMON/ADDVAR/ADMTRX(6,6,6),ADDFM(6),RTMTRX(6,6)
      COMMON/DOTCOF/XUDOT,YVDOT,YRDOT,YPDOT,ZWDOT,ZQDOT,KVDOT,KPDOT,
     1              KRDOT,MWDOT,MQDOT,NVDOT,NPDOT,NRDOT
C
      COMMON/COMOVE/XC,YC,ZC
      LOGICAL PNT
C
      COMMON /ADDPRNT/ IR1,IR2,IR3,IR4,IR5,IP1,IP2,IP3,IP4,IP5,IP6,IP7,
     1               IP8,IP9,IP10,PNT(15)
C
      COMMON /OPTION/ IDOF,IOPTN(20)
C
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      COMMON /OT.TOO/ TO,UO,VO,WO,PO,QO,RO,PHIO,THETAO,PSIO
C
      COMMON /INTGRL/ DT,DTMIN,TMAX,AE(15),EPS(15), STATE
C
C       DT             - STEP SIZE FOR CALLS TO KUTMER, SEC
C       DTMIN          - MINIMUM STEP SIZE TO BE USED BY KUTMER, SEC
C       TMAX           - SIMULATION STOP TIME
C       AE(1-15)       - ABSOLUTE INTEGRATION ERROR CRITERIA FOR STATE
C                        VECTOR, Y(1-15)
C       EPS(1-15)      - RELATIVE ERROR CRITERIA FOR Y(1-15)
C
      COMMON /XCONTL/ ICONT,IC1(10),IC2(10),IACT(10),JACT(10),CV1(10),
     1                CV2(10),CV3(10),CV4(10),CRIN1(16),CRIN2(16),
     2                COIN1(10),COIN2(10),COIN3(10),RELAR(2),CHECK(2),
     3                RATE(12),KACT(12)
      COMMON /OUTX  / IPUT(5),IPRINT(5),JPA,NRUN,IPRINT
C
      COMMON /HEADER/ TITLE(10)
C
C       PRINT PAGE 1
C
        IF(JPA.EQ.0) WRITE(IPR,600) NRUN,(TITLE(I),I=1,10)
C
        JPA = JPA + 1
C       LOAD LINE FOR PAGE 1.
        PAGE1(1) = TIME
        PAGE1(2) = (SPEED/FTTOKN)/1.688
        PAGE1(3) = U
        PAGE1(4) = V
      PAGE1(5) = R*RADIAN
      PAGE1(6) = PHI*RADIAN
      PAGE1(7) = THETA*RADIAN
        PAGE1(8) = DRIFAN*RADIAN
        PAGE1(9) = PSI*RADIAN
        PAGE1(10) = XF
        PAGE1(11) = YF
      PAGE1(12) = RE
      PAGE1(13) = S
C       PRINT JPA-TH LINE ON PAGE1
C
      WRITE(IP6,601) (PAGE1(I),I=1,13)
C
C       LOAD PAGES 2-5 INTO PAGE(1-4,I,J)
C
         DO 1 I=1,4
          PAGE(I,JPA,1)=TIME
          PAGE(I,JPA,2)=(SPEED/FTTOKN)/1.688
 1       CONTINUE
      PAGE(1,JPA,3) = PITCHS
      PAGE(1,JPA,4) = PITCHP
      PAGE(1,JPA,5) = RPRNS
      PAGE(1,JPA,6) = RPRNP
C
      PAGE(2,JPA,3) = PITCHS
      PAGE(2,JPA,4) = PITCHP
         PAGE(2,JPA,5) = RPRNS
         PAGE(2,JPA,6) = RPRNP
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C
      DO 101 I=1,4
  101   PAGE(1,JPA,I+6) = FINANG(I)*RADIAN
      PAGE(1,JPA,11) = RUDANG(1)*RADIAN
      PAGE(1,JPA,12)=RUDANG(2)*RADIAN
      PAGE(1,JPA,13)=PRUDAP
      PAGE(1,JPA,14)=PRUDAP
      PAGE(3,JPA,03)=PRUDAP
      PAGE(3,JPA,04)=PRUDAP
      PAGE(3,JPA,5) = RADIAN*RUDANG(1)
      PAGE(3,JPA,6) = RADIAN*RUDANG(2)
C
      PAGE(4,JPA,3) = RADIAN*FINANG(1)
      PAGE(4,JPA,4) = RADIAN*FINANG(2)
      PAGE(4,JPA,5) = RADIAN*FINANG(3)
      PAGE(4,JPA,6) = RADIAN*FINANG(4)
      PAGE(4,JPA,3) =  FINANG(1)*RADIAN
      PAGE(4,JPA,4) =  FINANG(2)*RADIAN
      PAGE(4,JPA,5) =  FINANG(3)*RADIAN
      PAGE(4,JPA,6) =  FINANG(4)*RADIAN
C
         DO 9 I=1,6
           PAGE(2,JPA,6+I) = PROPEX(I)
           PAGE(3,JPA,6+I) =  THREX(I)
           PAGE(4,JPA,6+I) =     FEX(I)
C        CONTINUE
C     RETURN IF FULL PAGE NOT REACHED
      IF(JPA.LT.40.AND.IOPT.NE.2) RETURN
C
C     PRINT PAGES 2-4.
C
C     PAGE 2
       WRITE(IP6,602) NRUN,(TITLE(I),I=1,18)
       WRITE(IP6,603) ((PAGE(1,J,K),K=1,14),J=1,JPA)
C
C     PAGE 3
       IF(IOPTN(2).EQ.0) GO TO 888
       WRITE(IP6,604) NRUN,(TITLE(I),I=1,18)
       WRITE(IP6,605) ((PAGE(2,J,K),K=1,12),J=1,JPA)
C
C     PAGE 4
       WRITE(IP6,606) NRUN,(TITLE(I),I=1,18)
       WRITE(IP6,607) ((PAGE(3,J,K),K=1,12),J=1,JPA)
C
C     PAGE 5
       WRITE(IP6,608) NRUN,(TITLE(I),I=1,18)
       WRITE(IP6,609) ((PAGE(4,J,K),K=1,12),J=1,JPA)
C
C
  888 CONTINUE
      JPA = 0
C
C     PAGE 1 FORMAT
C
  600 FORMAT(1H1,///,24H QUATH SIMULATION NUMBER,I4,10X,18A4,//,1H ,
     1T3,4HTIME,T13,5HSPEED,T21,1HU,T29,1HV,T37,4HTURN,
     *T47,4HROLL,T54,5HPITCH,T62,5HDRIFT,T71,7HHEADING,T84,1HX,
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     1T93,1HY,T100,1HZ,T114,8HDISTANCE,/,
     CT4,2HIN,T14,2HIN,T21,2HIN,T28,2HIN,T37,4HRATE,T44,5HANGLE,
     DT54,5HANGLE,T62,5HANGLE,T71,5HANGLE,T84,2HIN,T97,2HIN,
     ET102,2HIN,T109,8HTRAVELED,/,
     FT4,3HSEC,T12,5HKNOTS,T19,5HM/SEC,T26,5HM/SEC,T35,7HDEG/SEC,
     GT46,6HIN DEG,T55,6HIN DEG,T62,6HIN DEG,T71,6HIN DEG,T80,
     H6HMETERS,T91,6HMETERS,T100,6HMETERS,T109,6HMETERS,//)
601   FORMAT(1H ,F6.2,F10.2,2F7.2,F11.3,F10.2,2F8.2,F8.1,F11.1,3F8.1)
C
C      PAGE 2 FORMAT
C
  602 FORMAT(1H1,///,24H SWATH SIMULATION NUMBER,I4,10X,10A8,//,
     1130H    TIME    SPEED       PROPELLER          PROPELLER          FIN  ANGLE
     2S  IN  DEGREES         RUDDER ANGLE IN DEG   RUDDER POSITION IN METE
     3RS,/,110H      IN         IN      PITCH IN DEG          RPM            ROW
     4 BOW       AFT    AFT             AFT        AFT             BOW       BOW,/,
     5130H      SEC    KNOTS        STBD    PORT     STBD    PORT         STBD   POR
     6T    STBD   PORT          STBD         PORT            STBD      PORT,//)
  603 FORMAT(1H ,F7.2,F7.2,F8.2,F7.2,3F8.1,F7.1,F8.1,F6.1,F12.1,F10.1,
     1F13.2,F8.2)
C
C      PAGE 3 FORMATS
C
604   FORMAT(1H1,///,24H SWATH SIMULATION NUMBER,I4,10X,10A8,//,1H ,
     1   T7,4HTIME,T16,5HSPEED,T26,18HPROPELLER PITCH,T47,4HPROP,T57,
     2   4HPROP,T65,6HPROP X,T77,6HPROP Y,T89,6HPROP Z,T101,6HPROP K,
     3   T113,6HPROP M,T125,6HPROP N,/,1H,
     4   T8,2HIN,T18,2HIN,T28,11HIN  DEGREES,T48,3HRPM,T58,3HRPM,T64,
     5   8HFORCE IN,T76,8HFORCE IN,T88,8HFORCE IN,T101,6HMOMENT,T113,
     6   6HMOMENT,T125,6HMOMENT,/,1H ,
     7   T8,3HSEC,T16,5HKNOTS,T27,4HSTBD,T37,4HPORT,T47,4HSTBD,T57,
     8   4HPORT,T65,6HNEWTON,T77,6HNEWTON,T89,6HNEWTON,T102,4HNT-M,T114,
     9   4HNT-M,T126,4HNT-M/)
605   FORMAT(1H ,F9.2,3F10.2,2F10.1,6F12.4)
C
C      PAGE 4 FORMATS
C
606   FORMAT(1H1,///,24H SWATH SIMULATION NUMBER,I4,10X,10A8,//,1H ,
     1   T7,4HTIME,T16,5HSPEED,T24,19HBOW RUDDER POSITION,T44,
     2   17HAFT RUDDER ANGLES,T64,8HRUDDER X,T76,8HRUDDER Y,T88,
     3   8HRUDDER Z,T100,8HRUDDER K,T112,8HRUDDER M,T124,8HRUDDER N,/1X,
     4   T8,2HIN,T18,2HIN,T29,10HIN  METERS,T45,11HIN DEGREES,T64,
     5   8HFORCE IN,T76,8HFORCE IN,T88,8HFORCE IN,T101,6HMOMENT,T113,
     6   6HMOMENT,T125,6HMOMENT,/,1H,
     7   T8,3HSEC,T16,5HKNOTS,T27,4HSTBD,T37,4HPORT,T47,4HSTBD,T57,
     8   4HPORT,T66,6HNEWTON,T78,6HNEWTON,T90,6HNEWTON,T102,4HNT-M,
     9   T114,4HNT-M,T126,4HNT-M,/)
607   FORMAT(1H ,F9.2, 5F10.2,6F12.4)
C
C       PAGE 5 FORMATS
C
608   FORMAT(1H1,///,24H SWATH SIMULATION NUMBER,I4,10X,10A8,//,1H ,
     1   T7,4HTIME,T16,5HSPEED,T27,14HBOW FIN ANGLES,T47,
     2   14HAFT FIN ANGLES,T66,5HFIN X,T78,5HFIN Y,T90,5HFIN Z,T102,
     3   5HFIN K,T114,5HFIN M,T126,5HFIN N,/,1H ,
     4   T8,2HIN,T18,2HIN,T28,10HIN DEGREES,T48,10HIN DEGREES,T64,
     5   8HFORCE IN,T76,8HFORCE IN,T88,8HFORCE IN,T101,6HMOMENT,T113,
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-     6HMOM[illegible]T,T105,6HMOMENT,/,1H ,
7     T6,7HSPEC,T16,5HKNOTS,T27,4HST[illegible],T37,4[illegible]T,T47,4HST[illegible],T57,
8     4 PO[illegible]T,T6[illegible],6HME[illegible]T[illegible],T78,6HNEUTON,T90,[illegible]NEUTON,T102,4H[illegible]T-[illegible],
9     T114,4[illegible]T-[illegible],T126,4H[illegible]-[illegible],/)
6[illegible]  FORMAT(1H ,F9.2,5F10.2,6E12.4)
      RETURN
      END
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      SUBROUTINE PROPOR
      REAL KPT,KPTS,KPTH
      REAL M1,M2,M1M2
C
C     PROGRAM TO COMPUTE PROPULSION FORCES AND MOMENTS
C
      COMMON /STATEO/ UO,VO,WO,PO,QO,RO,PHIO,THETAO,PSIO
      COMMON /PROPVR/ PDIA, PROARM(3), PRPMS, PRPMP, PITCHS, PITCHP,
     1                PROPT(4)
C
C
      COMMON /CONST / RADIAN, RHOA, RHOA2, RHOW, RHOW2, EITOM
      COMMON /STATE / U,V,W,P,Q,R,PHI,THETA,PSI,XE,YE,ZE,SPEED,G,
     1                PRIFAN,COSPHI,COSTHE,COSPSI,SINPHI,SINTHE,SINPSI,
     1                TMTRX(3,3),TIME
C
      DIMENSION PRRTIO(13),PJMID(11),PJHI(5),PJLO(4),VALHI(65),VALLO(52)
     1,VALMID(143)
      DATA PRRTIO/-4.,-3.,-2.,-1.5,-1.0775,-.5,0.,.5,1.0775,1.5,2.,3.,
     14./
      DATA PJMID/-1.,-.8,-.6,-.4,-.2,0.,.2,.4,.6,.8,1.0/
      DATA PJHI/.2,.4,.6,.8,1./
      DATA PJLO/-1.,-.8,-.6,-.4/
      DATA VALHI/3*-20.,-17.,-16.,2*-15.,3*-10.,-7.,-2.5,-1.,
     1-3.7,-3.5,-4.3,-3.7,-3.7,-2.8,-2.6,-2.5,-2.1,-1.16,-.5,.08,.41,
     2-3.2,-3.4,-2.6,-2.3,-2.0,-1.55,-1.25,-1.05,-.6,-.16,.13,.55,.72,
     3-1.85,-2.07,-2.07,-1.65,-1.5,-1.1,-.77,-.52,-.12,.11,.38,.72,.84,
     4-1.65,-1.6,-1.7,-1.48,-1.2,-.94,-.49,-.26,-.04,.27,.57,.83,.88/
      DATA VALLO/-.82,-.86,-.64,-.39,-.1,.16,.34,.66,.94,1.13,1.5,1.52,
     11.6,-.95,-.9,-.49,-.2,.08,.3,.55,.86,1.10,1.52,1.9,1.9,2.,
     2-.76,-.6,-.1,.15,.4,.66,1.05,1.38,1.75,2.,2.5,2.5,2.,
     3-.35,0.,.64,.95,1.2,1.6,2.5,3.0,3.5,3.5,4.0,4.0,3.7/
      DATA VALMID/-.82,-.86,-.64,-.39,-.1,.16,.34,.66,.94,1.13,1.5,1.52,
     11.6,-.9,-.84,-.72,-.58,-.24,.04,.21,.52,.68,.78,1.04,1.1,1.18,
     2-.9,-.9,-.75,-.6,-.35,-.07,.1,.04,.44,.58,.78,.8,.94,
     3-.81,-.79,-.72,-.62,-.43,-.15,.04,.26,.56,.67,.8,.86,1.07,
     4-.82,-.76,-.67,-.56,-.44,-.2,.07,.32,.62,.79,.85,1.0,1.0,
     5-.84,-.8,-.66,-.55,-.4,-.22,0.,.3,.6,.77,.9,.93,.98,
     6-.89,-.8,-.77,-.66,-.4,-.24,-.04,.23,.5,.71,.87,.99,.96,
     7-.97,-1.01,-.93,-.76,-.6,-.35,-.1,.14,.38,.60,.81,.96,.94,
     8-1.17,-1.17,-1.02,-.85,-.68,-.52,-.2,.07,.07,.51,.74,.74,.80,
     9-1.5,-1.5,-1.28,-1.18,-1.,-.74,-.33,-.1,.16,.4,.54,.88,.9,
     K-1.65,-1.6,-1.7,-1.48,-1.2,-.94,-.49,-.26,.04,.27,.57,.83,.88/
      PJ=(.82*SQRT(U*U+V*V)*60.)/(PRPMP*PDIA)
      PJ=(.82*SQRT(U*U+V*V)*60.)/(PRPMS*PDIA)
      II=1
      JJ=1
      IF(PJ.LT.-1.)GO TO 1
      IF(PJ.GT.1.) GO TO 2
      CALL TABQV(PRRTIO,PJMID,VALMID,13,11,PITCHP,PJ,6,1,II,JJ,PKT,IER)
      GO TO 3
    1 PJ=1./PJ
      CALL TABQV(PRRTIO,PJLO,VALLO,13,4,PITCHP,PJ,6,1,II,JJ,PKT,IER)
      GO TO 3
    2 PJ=1./PJ
      CALL TABQV(PRRTIO,PJHI,VALHI,13,5,PITCHP,PJ,6,1,II,JJ,PKT,IER)
    3 CONTINUE
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      II=1
      JJ=1
      IF(SJ.LT.-1.) GO TO 4
      IF(SJ.GT.1.) GO TO 5
      CALL TABDV(PERTIC.PUMID.VALMID.13,11.PITCHS.SJ.6.1,II.JJ.SKT.IER)
      GO TO 6
    4 SJ=1./SJ
      CALL TABDV(PERTIC.PULO.VALLO.13,4,PITCHS.SJ.6,1,II.JJ.SKT.IER)
      GO TO 6
    5 SJ=1./SJ
      CALL TABDV(PERTIC.PUHI.VALHI.13.5,PITCHS.SJ.6.1,II.JJ.SKT,IER)
    6 CONTINUE
      A=SKT*RHOMS*PRPMS*RHOW*(PDIA**4.)/3600.
      B=SKT*RHOMP*PRPMP*RHOW*(PDIA**4.)/3600.
      PROPFM(1)=A+B
      PROPFM(2)=0.
      PROPFM(3)=0.
      PROPFM(4)=0.
      PROPFM(5)=PROPFM(1)*PROPFM(3)
      PROPFM(6)=(B-A)*PROPFM(2)
      RETURN
      END
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      SUBROUTINE RUDDER
C
C     PROGRAM TO COMPUTE RUDDER FORCES AND MOMENTS
C
      REAL LENGTH
      COMMON /SCALE/ SCFACT,LENGTH,MASS,IXX,IYY,IYZ,IXY,IXZ,IZZ
      COMMON /STATES/ T0,U0,V0,W0,P0,Q0,R0,PHI0,THETA0,PSI0
      COMMON /RUDPAR/RUDANG(2),UUVEL(10),RALFA(10),AXRUD(100),AYRUD(100),
     1             AKRUD(100),AMRUD(100),RATIO,RUDANG(2),NUMUUV,NUMRAL
     2         ,RUDPSN,CRUDOS,BRUDAP,PRUDPM,RUDER(4)
     1,XRUD(2),YRUD(2),ZRUD(2)
     1,RUDARM
     1,RRDARM,HSPAN
C
      COMMON /CONST / RADIAN, RHOA, RHOA2, RHOW, RHOW2,FTTOM
C
      COMMON /STATE / U,V,W,P,Q,R,PHI,THETA,PSI,XE,YE,ZE,Q,SPEED,
     1                 DRIFAN,COSPHI,COSTHE,COSPSI,SINPHI,SINTHE,SINPSI,
     2                 TMTRX(3,3),TIME
C
      DIMENSION VV1(2),VV2(2),VV3(5),DYRUD(20)
      DATA VV1/0.,.4/,VV2/.287,.391/,VV3/10.,.15,.20,.25,.33./
      DATA DYRUD/2.5,6.3,-1.0,1.5,3.2,6.6,.8,0.6,4.1,6.6,1.0,7.2,4.6,
     17.0,2.0,4.1,4.0,5.4,1.3,2.9/
C
      SPEED=SQRT(U*U+V*V)
      CALL TOTVEL(U,V,W,P,Q,R,XRUD(1),YRUD(1),ZRUD(1),U1,V1,W1)
      CALL TOTVEL(U,V,W,P,Q,R,XRUD(2),YRUD(2),ZRUD(2),U2,V2,W2)
      BAM1=ATAN(V1/U1)
      BAM2=ATAN(V2/U2)
      RALFA1=RUDANG(1)
      RALFA2=RUDANG(2)
      II=1
      JJ=1
      CALL TAB2V(RALFA,UUVEL,AXRUD,NUMRAL,NUMUUV,RALFA1,SPEED,6,1,II,JJ,
     1AXR1,IER)
      CALL TAB2V(RALFA,UUVEL,AYRUD,NUMRAL,NUMUUV,RALFA1,SPEED,6,0,II,JJ,
     1AYR1,IER)
      CALL TAB2V(RALFA,UUVEL,AKRUD,NUMRAL,NUMUUV,RALFA1,SPEED,6,0,II,JJ,
     1AKR1,IER)
      CALL TAB2V(RALFA,UUVEL,AMRUD,NUMRAL,NUMUUV,RALFA1,SPEED,6,0,II,JJ,
     1AMR1,IER)
      II=1
      JJ=1
      CALL TAB2V(RALFA,UUVEL,AXRUD,NUMRAL,NUMUUV,RALFA2,SPEED,6,1,II,JJ,
     1AXR2,IER)
      CALL TAB2V(RALFA,UUVEL,AYRUD,NUMRAL,NUMUUV,RALFA2,SPEED,6,0,II,JJ,
     1AYR2,IER)
      CALL TAB2V(RALFA,UUVEL,AKRUD,NUMRAL,NUMUUV,RALFA2,SPEED,6,0,II,JJ,
     1AKR2,IER)
      CALL TAB2V(RALFA,UUVEL,AMRUD,NUMRAL,NUMUUV,RALFA2,SPEED,6,0,II,JJ,
     1AMR2,IER)
      AXR1=-ABS(AXR1)
      AXR2=-ABS(AXR2)
      AYR1=AYR1/2.
      AYR2=AYR2/2.
      AKR1=AKR1/2.
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      AYR2=AYR2/2.
      AKR1=AKR1/2.
      AKR2=AKR2/2.
      ANR1=ANR1/2.
      ANR2=ANR2/2.
      RUDFM(1)=(AXR1+AXR2)*ARATIO
      RUDFM(2)=(AYR1+AYR2)*ARATIO
      RUDFM(3)=0.0
      RUDFM(4)=(AKR1+AKR2)*ARATIO
      RUDFM(5)=(AYR1+AYR2)*(RUDARM-((ZF-SINTHE*XRUD(1))/2.))*ARATIO
      RUDFM(6)=(ANR1+ANR2)*ARATIO
      DO 9 K=1,6
    9 RUDFM(K)=RUDFM(K)*SQRT(1.+((ZF-SINTHE*XRUD(1))/3.9))
C
C
C
C FIXED FORWARD RUDDER
C
C
      VAR1=DTIFAN*RADIAN
      VAR2=R*LENGTH/U
      VAR3=U/.5144
      IF(RRUDAS.GT.0.) GO TO 72
      VAR1=-VAR1
      VAR2=-VAR2
   72 CONTINUE
      CALL TAB3V(VV1,VV2,VV3,RXRUD,2,2,5,VAR1,VAR2,VAR3,10,1,1,1,1,RYR,
     *ITR)
      FFF=(RRUDAS-RRUDAP)/RRSPAN
      BCWY=5*LENGTH*LENGTH*U*U*RYR*FFF*.1
      BCWX=-ABS(BCWY)/7.
      BCWK=-(21.72+RRUDAS+RRUDAP)*.5*BCWY
      BCWN=19.42*BCWY-11.43*BCWY*SIGN(1.,FFF)
      RUDFM(1)=RUDFM(1)+BCWX
      RUDFM(2)=RUDFM(2)+BCWY
      RUDFM(4)=RUDFM(4)+BCWK
      RUDFM(6)=RUDFM(6)+BCWN
      RUDFM(5)=RUDFM(5)+BCWY*RUDARM
      RETURN
      END
```

```
      SUBROUTINE TLU2V(V1,V2,OF,N1,N2,ARG1,ARG2,IP,KEY,II,JJ,VAL,IER)
      DIMENSION V1(1),V2(1),OF(1)
      REAL X1,X2,X1X2
C         TABLE LOOKUP FOR 2 VARIABLES
C           OF    -OBSERVED VALUES STORED COLUMN WISE ACCORDING TO V1,V2
C           N1    - NO. OF V1-S
C           N2    - NO. OF V2-S
C           IER    - 0 IN RANGE OTHERWISE OUT OF RANGE
C           IP    - UNIT FOR INTERMEDIATE PRINTOUT
C           KEY    - 0 DO NOT PERFORM SEARCH. USE PREVIOUS POINTS
C           II    - CLOSEST POINT TO ARG1 S.T. V1(II).LE.ARG1.
C           JJ    - CLOSEST POINT TO ARG2 S.T. V2(JJ).LE.ARG2
C           VAL    - RESULTING INTERPOLATED VALUE.
C           V1,V2    FIRST AND SECOND VARIABLE ARRAYS.  THEY SHOULD BE
C                    STORED IN MONOTONICALLY INCREASING ORDER STARTING
C                    WITH MOST NEGATIVE VALUE.    ALL V1 OR V2 VALUES
C                    MUST BE UNIQUE
      IF(KEY.EQ.0)GO TO 100
      CALL NGHBR1(V1,ARG1,II, N1,IER1,X1)
      CALL NGHBR1(V2,ARG2,JJ,N2,IER2,X2)
      IER=IER1+10*IER2
      X1X2=X1*X2
      A00 = 1.-X1-X2+X1X2
      A10 = X1-X1X2
      A01 = X2-X1X2
      A11 = X1X2
      I00 = II+N1*(JJ-1)
      I10 = I00+1
      I01 = I00+N1
      I11 = I00+1+N1
  100 VAL = OF(I00)*A00  +  OF(I10)*A10
     *      +OF(I01)*A01  +  OF(I11)*A11
C           TESTING
      RETURN
      END
```

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```
      SUBROUTINE TAB3V(V1,V2,V3,OB,N1,N2,N3,ARG1,ARG2,ARG3,IO,KEY,
     *                 II,JJ,KK,VAL,IER)
C     TABLE LOOKUP FOR 3 VARIABLES. V1,V2,V3.
C        OB       - OBSERVATIONS STORED COLUMN WISE ACCORDING TO V1,V2,V3.
C        N1       - NO. OF V1-S
C        N2       - NO. OF V2-S
C        N3       - NO. OF V3-S
C        IER      - 0 IN RANGE
C                   1 OUT OF RANGE
C        IO       - INTERMEDIATE PRINTOUT UNIT.
C        KEY      - 0 DO NOT PERFORM SEARCH. USE PREVIOUS POINTS.
C        II       - CLOSEST POINT TO ARG1 S.T. V1(II).LE.ARG1.
C        JJ       - CLOSEST POINT TO ARG2 S.T. V2(JJ).LE.ARG2.
C        KK       - CLOSEST POINT TO ARG3 S.T. V3(KK).LE.ARG3.
C        VAL      - RESULTING INTERPOLATED VALUE.
C        V1,V2,V3 FIRST,SECOND,AND THIRD VARIABLE ARRAYS.
C                 V1-V3 SHOULD EACH BE STORED IN MONOTONICALLY
C                 INCREASING ORDER STARTING WITH MOST NEGATIVE VALUE.
C                 ALL V1,V2,OR V3 VALUES MUST BE UNIQUE
      DIMENSION V1(1),V2(1),V3(1),OB(1)
      REAL M1,M2,M3,M1M2,M1M3,M2M3,M1M2M3
      IF(KEY.EQ.0) GO TO 100
C----------
C     PERFORM SEARCH
C----------
      CALL NGHBR1(V1,ARG1,II,N1,IER1,M1)
      CALL NGHBR1(V2,ARG2,JJ,N2,IER2,M2)
      CALL NGHBR1(V3,ARG3,KK, N3,IER3,M3)
      IER= IER1+10*IER2+100*IER3
      M1M2 = M1*M2
      M1M3 = M1*M3
      M2M3 = M2*M3
      M1M2M3 = M1*M2*M3
      A000= 1.-M1-M2-M3+M1M2+M1M3+M2M3-M1M2M3
      A100= M1-M1M2-M1M3+M1M2M3
      A001= M3-M1M3-M2M3+M1M2M3
      A010= M2-M1M2-M2M3+M1M2M3
      A110= M1M2-M1M2M3
      A101= M1M3-M1M2M3
      A011= M2M3-M1M2M3
      A111 = M1M2M3
      I000 = II+N1*(JJ-1)+N1*N2*(KK-1)
      I100 = I000 +1
      I010 = I000 + N1
      I001 = I000 + N1*N2
      I110 = I000 +1 + N1
      I101 = I000 +1 + N1*N2
      I011 = I000 +N1*(1+N2)
      I111 = I101 +N1
  100 VAL  = OB(I000)*A000   +   OB(I100)*A100
     1       +OB(I010)*A010  +   OB(I001)*A001
     2       +OB(I110)*A110  +   OB(I101)*A101
     3       +OB(I011)*A011  +   OB(I111)*A111
      RETURN
      END
```

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```
      SUBROUTINE TOTVEL(UU,VV,WW,PP,QQ,RR,XDV,YDV,ZDV,UTOT,VTOT,WTOT)
C     PROGRAM TO COMPUTE TOTAL INFLOW VELOCITIES
      UTOT=UU-RR*YDV+QQ*ZDV
      VTOT=VV-PP*ZDV+RR*XDV
      WTOT=WW-QQ*XDV+PP*YDV
      RETURN
      END
```

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```
      SUBROUTINE TURNON
C
C     THIS PROGRAM TURNS ON ALL PRINT OUT SWITCHES AND SETS TMAX,THE
C     SIMULATION END TIME TO ZERO SO THAT RUN TERMINATES
      LOGICAL PNT
      COMMON /OPRINT/ IFILL(15),PNT(15)
C
      COMMON /CNTROL/ DT,DTMIN,TMAX,A(15),EPS(15),NSTATE
C
      TMAX = 0.0
C
      DO 1 I=1,15
        PNT(I) = .TRUE.
    1 CONTINUE
      RETURN
      END
```

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APPENDIX C

SAMPLE OUTPUT FOR A TURN MANEUVER PREDICTION

```
[illegible]
[illegible]      = 0.0,
[illegible]      = .[illegible]+02,
[illegible]      = 0.0,
[illegible]      = [illegible].0,
[illegible]      = 0.0,
[illegible]      = 0.0,
[illegible]      0.0,
[illegible]      = 0.0,
[illegible]      = 0.0,
[illegible]      = 0.0,
YC               = 0.0,
[illegible]      = 0.0,
[illegible]CFACT = .[illegible]+0[illegible],
L[illegible]     = .[illegible]+02,
[illegible]      = .[illegible]+07,
IXX              = .[illegible]+0[illegible],
IYY              = .4[illegible]+01,
IZZ              = .4[illegible]+01,
IXY              = .0,
IXZ              = 0.0,
IYZ              = 0.0,
[illegible]IA    = .[illegible]+01,
[illegible]      = -.[illegible]+02, .[illegible]+02, .[illegible]+01,
[illegible]      = .1[illegible]+0[illegible],
[illegible]      = .1[illegible]+07,
[illegible]      = .1[illegible]+01,
[illegible]      = .1[illegible]+01,
[illegible]      = [illegible].0, [illegible].0, [illegible].3, [illegible].3,
[illegible]      = .[illegible]+[illegible], .7[illegible]+01, .[illegible]+02, .[illegible]+0[illegible],
[illegible]      = .1[illegible]+[illegible], .1[illegible]+0[illegible], -.[illegible]+02, -.[illegible],
Y[illegible]     = .[illegible]+01, -.[illegible]+01, .[illegible]+01, -.[illegible]+01,
```

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[illegible]

THERE ARE [illegible] 2 ACTIONS

CONTROL CONDITION				COMMAND CHANGE	TO		RATE	
TIME	G.T.	17.[illegible]	SEC	RUD-AFT-[illegible]	-35.00	DEG/S	5.00	ONCE
TIME	G.T.	17.95	SEC	RUD-AFT-F	-35.00	DEG/S	5.00	ONCE

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ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NON-DIMENSIONAL	SPEED KTS	Y FORCE NT	K MOMENT NT-M	N MOMENT NT-M
-6.00	-4.00	-.30	5.00	-.286721E+06	.304248E+07	.233041E+07
0.00	-4.00	-.30	5.00	-.286721E+06	.304248E+07	.233041E+07
6.00	-4.00	-.30	5.00	-.286721E+06	.304248E+07	.233041E+07
-6.00	0.00	-.30	5.00	-.176988E+06	.245987E+07	.517868E+07
0.00	0.00	-.30	5.00	-.176988E+06	.245987E+07	.517868E+07
6.00	0.00	-.30	5.00	-.176988E+06	.245987E+07	.517868E+07
-6.00	4.00	-.30	5.00	-.672556E+05	.187727E+07	.802696E+07
0.00	4.00	-.30	5.00	-.672556E+05	.187727E+07	.802696E+07
6.00	4.00	-.30	5.00	-.672556E+05	.187727E+07	.802696E+07
-6.00	-4.00	0.00	5.00	-.109733E+06	.582602E+06	-.284828E+07
0.00	-4.00	0.00	5.00	-.109733E+06	.582602E+06	-.284828E+07
6.00	-4.00	0.00	5.00	-.109733E+06	.582602E+06	-.284828E+07
-6.00	0.00	0.00	5.00	0.	0.	0.
0.00	0.00	0.00	5.00	0.	0.	0.
6.00	0.00	0.00	5.00	0.	0.	0.
-6.00	4.00	0.00	5.00	.109733E+06	-.582602E+06	.284828E+07
0.00	4.00	0.00	5.00	.109733E+06	-.582602E+06	.284828E+07
6.00	4.00	0.00	5.00	.109733E+06	-.582602E+06	.284828E+07
-6.00	-4.00	.30	5.00	.672556E+05	-.187727E+07	-.802696E+07
0.00	-4.00	.30	5.00	.672556E+05	-.187727E+07	-.802696E+07
6.00	-4.00	.30	5.00	.672556E+05	-.187727E+07	-.802696E+07
-6.00	0.00	.30	5.00	.176988E+06	-.245987E+07	-.517868E+07
0.00	0.00	.30	5.00	.176988E+06	-.245987E+07	-.517868E+07
6.00	0.00	.30	5.00	.176988E+06	-.245987E+07	-.517868E+07
-6.00	4.00	.30	5.00	.286721E+06	-.304248E+07	-.233041E+07
0.00	4.00	.30	5.00	.286721E+06	-.304248E+07	-.233041E+07
6.00	4.00	.30	5.00	.286721E+06	-.304248E+07	-.233041E+07
-6.00	-4.00	-.30	10.00	-.109733E+07	.776802E+07	.517868E+07
0.00	-4.00	-.30	10.00	-.109733E+07	.776802E+07	.517868E+07
6.00	-4.00	-.30	10.00	-.109733E+07	.776802E+07	.517868E+07
-6.00	0.00	-.30	10.00	-.672556E+06	.569655E+07	.155360E+08
0.00	0.00	-.30	10.00	-.672556E+06	.569655E+07	.155360E+08
6.00	0.00	-.30	10.00	-.672556E+06	.569655E+07	.155360E+08
-6.00	4.00	-.30	10.00	-.247784E+06	.362508E+07	.258934E+08
0.00	4.00	-.30	10.00	-.247784E+06	.362508E+07	.258934E+08
6.00	4.00	-.30	10.00	-.247784E+06	.362508E+07	.258934E+08
-6.00	-4.00	0.00	10.00	-.424772E+06	.207147E+07	-.103574E+08
0.00	-4.00	0.00	10.00	-.424772E+06	.207147E+07	-.103574E+08
6.00	-4.00	0.00	10.00	-.424772E+06	.207147E+07	-.103574E+08
-6.00	0.00	0.00	10.00	0.	0.	0.
0.00	0.00	0.00	10.00	0.	0.	0.
6.00	0.00	0.00	10.00	0.	0.	0.
-6.00	4.00	0.00	10.00	.424772E+06	-.207147E+07	.103574E+08
0.00	4.00	0.00	10.00	.424772E+06	-.207147E+07	.103574E+08
6.00	4.00	0.00	10.00	.424772E+06	-.207147E+07	.103574E+08
-6.00	-4.00	.30	10.00	.247784E+06	-.362508E+07	-.258934E+08

ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE DEG-DIMENSIONAL	SPEED KTS	Y FORCE NT	K MOMENT NT-M	N MOMENT NT-M
0.00	-4.00	.30	10.00	.247714E+06	-.362508E+07	-.258934E+08
6.00	-4.00	.30	10.00	.247714E+06	-.362508E+07	-.258934E+08
-6.00	0.00	.30	10.00	.672556E+06	-.569655E+07	-.155460E+08
0.00	0.00	.30	10.00	.672556E+06	-.569655E+07	-.155460E+08
6.00	0.00	.30	10.00	.672556E+06	-.569655E+07	-.155360E+08
-6.00	4.00	.30	10.00	.109733E+07	-.776802E+07	-.517868E+07
0.00	4.00	.30	10.00	.109733E+07	-.776802E+07	-.517868E+07
6.00	4.00	.30	10.00	.109733E+07	-.776802E+07	-.517868E+07
-6.00	-4.00	-.30	15.00	-.213448E+07	.167789E+08	-.233041E+07
0.00	-4.00	-.30	15.00	-.213448E+07	.167789E+08	.139824E+08
6.00	-4.00	-.30	15.00	-.213448E+07	.167789E+08	.302953E+08
-6.00	0.00	-.30	15.00	-.111503E+07	.116520E+08	.233041E+08
0.00	0.00	-.30	15.00	-.111503E+07	.116520E+08	.396169E+08
6.00	0.00	-.30	15.00	-.111503E+07	.116520E+08	.559298E+08
-6.00	4.00	-.30	15.00	-.955738E+05	.652514E+07	.489385E+08
0.00	4.00	-.30	15.00	-.955738E+05	.652514E+07	.652514E+08
6.00	4.00	-.30	15.00	-.955738E+05	.652514E+07	.815642E+05
-6.00	-4.00	0.00	15.00	-.101945E+07	.512690E+07	-.419473E+08
0.00	-4.00	0.00	15.00	-.101945E+07	.512690E+07	-.256345E+08
6.00	-4.00	0.00	15.00	-.101945E+07	.512690E+07	-.932163E+07
-6.00	0.00	0.00	15.00	0.	0.	-.163128E+08
0.00	0.00	0.00	15.00	0.	0.	0.
6.00	0.00	0.00	15.00	0.	0.	.163128E+08
-6.00	4.00	0.00	15.00	.101945E+07	-.512690E+07	.932163E+07
0.00	4.00	0.00	15.00	.101945E+07	-.512690E+07	.256345E+08
6.00	4.00	0.00	15.00	.101945E+07	-.512690E+07	.419473E+08
-6.00	-4.00	.30	15.00	.955738E+05	-.652514E+07	-.815642E+08
0.00	-4.00	.30	15.00	.955738E+05	-.652514E+07	-.652514E+08
6.00	-4.00	.30	15.00	.955738E+05	-.652514E+07	-.489385E+08
-6.00	0.00	.30	15.00	.111503E+07	-.116520E+08	-.559298E+08
0.00	0.00	.30	15.00	.111503E+07	-.116520E+08	-.396169E+08
6.00	0.00	.30	15.00	.111503E+06	-.116520E+08	-.233041E+08
-6.00	4.00	.30	15.00	.213448E+07	-.167789E+08	-.302953E+08
0.00	4.00	.30	15.00	.213448E+07	-.167789E+08	-.139824E+08
6.00	4.00	.30	15.00	.213448E+07	-.167789E+08	.233041E+07
-6.00	-4.00	-.30	20.00	-.379463E+07	.314864E+08	.227862E+08
0.00	-4.00	-.30	20.00	-.379463E+07	.356293E+08	.331436E+08
6.00	-4.00	-.30	20.00	-.379463E+07	.397723E+08	.435009E+08
-6.00	0.00	-.30	20.00	-.254863E+07	.248577E+08	.725015E+08
0.00	0.00	-.30	20.00	-.254863E+07	.290006E+08	.828589E+08
6.00	0.00	-.30	20.00	-.254863E+07	.331436E+08	.932163E+08
-6.00	4.00	-.30	20.00	-.130263E+07	.182290E+08	.122217E+09
0.00	4.00	-.30	20.00	-.130263E+07	.223719E+08	.132574E+09
6.00	4.00	-.30	20.00	-.130263E+07	.265149E+08	.142932E+09
-6.00	-4.00	0.00	20.00	-.124600E+07	.248577E+07	-.600727E+08
0.00	-4.00	0.00	20.00	-.124600E+07	.662871E+07	-.497153E+08

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ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NON-DIMENSIONAL	SPEED KTS	Y FORCE NT	K MOMENT NT-M	N MOMENT NT-M
6.00	-4.00	0.00	20.00	-.124600E+07	.107717E+08	-.393980E+08
-6.00	0.00	0.00	20.00	0.	-.414236E+07	-.103574E+08
0.00	0.00	0.00	20.00	0.	0.	0.
6.00	0.00	0.00	20.00	0.	.414236E+07	.103574E+08
-6.00	4.00	0.00	20.00	.124600E+07	-.107717E+08	.393980E+08
0.00	4.00	0.00	20.00	.124600E+07	-.662871E+07	.497153E+08
6.00	4.00	0.00	20.00	.124600E+07	-.248577E+07	.600727E+08
-6.00	-4.00	.30	20.00	.130263E+07	-.265149E+08	-.142932E+09
0.00	-4.00	.30	20.00	.130263E+07	-.223719E+08	-.132574E+09
6.00	-4.00	.30	20.00	.130263E+07	-.182290E+08	-.122217E+09
-6.00	0.00	.30	20.00	.254963E+07	-.331436E+08	-.932163E+08
0.00	0.00	.30	20.00	.254963E+07	-.290006E+08	-.828589E+08
6.00	0.00	.30	20.00	.254963E+07	-.248577E+08	-.725015E+08
-6.00	4.00	.30	20.00	.379463E+07	-.397723E+08	-.435069E+08
0.00	4.00	.30	20.00	.379463E+07	-.356293E+08	-.331436E+08
6.00	4.00	.30	20.00	.379463E+07	-.314864E+08	-.227862E+08
-6.00	-4.00	-.30	25.00	-.619460E+07	.352798E+08	.161834E+08
0.00	-4.00	-.30	25.00	-.575212E+07	.385164E+08	.485501E+08
6.00	-4.00	-.30	25.00	-.530965E+07	.417531E+08	.809169E+08
-6.00	0.00	-.30	25.00	-.398224E+07	.275117E+08	.113284E+09
0.00	0.00	-.30	25.00	-.353977E+07	.307484E+08	.145650E+09
6.00	0.00	-.30	25.00	-.309730E+07	.339851E+08	.178017E+09
-6.00	4.00	-.30	25.00	-.176988E+07	.197437E+08	.210384E+09
0.00	4.00	-.30	25.00	-.132741E+07	.229804E+08	.242751E+09
6.00	4.00	-.30	25.00	-.884942E+06	.262171E+08	.275117E+09
-6.00	-4.00	0.00	25.00	-.265483E+07	.453135E+07	-.647335E+08
0.00	-4.00	0.00	25.00	-.221236E+07	.776802E+07	-.971003E+08
6.00	-4.00	0.00	25.00	-.176988E+07	.110047E+08	-.129467E+09
-6.00	0.00	0.00	25.00	-.442471E+06	-.323668E+07	-.323668E+08
0.00	0.00	0.00	25.00	0.	0.	0.
6.00	0.00	0.00	25.00	.442471E+06	.323668E+07	.323668E+08
-6.00	4.00	0.00	25.00	.176988E+07	-.110047E+08	.129467E+09
0.00	4.00	0.00	25.00	.221236E+07	-.776802E+07	.971003E+08
6.00	4.00	0.00	25.00	.265483E+07	-.453135E+07	.647335E+08
-6.00	-4.00	.30	25.00	.884942E+06	-.262171E+08	-.275117E+09
0.00	-4.00	.30	25.00	.132741E+07	-.229804E+08	-.242751E+09
6.00	-4.00	.30	25.00	.176988E+07	-.197437E+08	-.210384E+09
-6.00	0.00	.30	25.00	.309730E+07	-.339851E+08	-.178017E+09
0.00	0.00	.30	25.00	.353977E+07	-.307484E+08	-.145650E+09
6.00	0.00	.30	25.00	.398224E+07	-.275117E+08	-.113284E+09
-6.00	4.00	.30	25.00	.530965E+07	-.417531E+08	-.809169E+08
0.00	4.00	.30	25.00	.575212E+07	-.385164E+08	-.485501E+08
6.00	4.00	.30	25.00	.619460E+07	-.352798E+08	-.161834E+08
-6.00	-4.00	-.30	28.00	-.677144E+07	.406009E+08	.365408E+08
0.00	-4.00	-.30	28.00	-.666043E+07	.446610E+08	.406009E+08
6.00	-4.00	-.30	28.00	-.654942E+07	.487210E+08	.446610E+08

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ROLL ANGLE DEG	DRIFT ANGLE DEG	YAW RATE NONDIMENSIONAL	SPEED KTS	Y FORCE NT	K MOMENT NT-M	N MOMENT NT-M
-6.00	0.00	-.30	28.00	-.344122E+07	.324807E+08	.158343E+09
0.00	0.00	-.30	28.00	-.333021E+07	.365408E+08	.162403E+09
6.00	0.00	-.30	28.00	-.321921E+07	.406009E+08	.167464E+09
-6.00	4.00	-.30	28.00	-.111007E+06	.243605E+08	.280146E+09
0.00	4.00	-.30	28.00	0.	.284206E+08	.284206E+09
6.00	4.00	-.30	28.00	.111007E+06	.324807E+08	.288266E+09
-6.00	-4.00	0.00	28.00	-.344122E+07	.406009E+07	-.125863E+09
0.00	-4.00	0.00	28.00	-.333021E+07	.812017E+07	-.121803E+09
6.00	-4.00	0.00	28.00	-.321921E+07	.121803E+08	-.117743E+09
-6.00	0.00	0.00	28.00	-.111007E+06	-.406009E+07	-.406009E+07
0.00	0.00	0.00	28.00	0.	0.	0.
6.00	0.00	0.00	28.00	.111007E+06	.406009E+07	.406009E+07
-6.00	4.00	0.00	28.00	.321921E+07	-.121803E+08	.117743E+09
0.00	4.00	0.00	28.00	.333021E+07	-.812017E+07	.121803E+09
6.00	4.00	0.00	28.00	.344122E+07	-.406009E+07	.125863E+09
-6.00	-4.00	.30	28.00	.111007E+06	-.324807E+08	-.288266E+09
0.00	-4.00	.30	28.00	0.	-.284206E+08	-.284206E+09
6.00	-4.00	.30	28.00	-.111007E+06	-.243605E+08	-.280146E+09
-6.00	0.00	.30	28.00	.321921E+07	-.406009E+08	-.167464E+09
0.00	0.00	.30	28.00	.333021E+07	-.365408E+08	-.162403E+09
6.00	0.00	.30	28.00	.344122E+07	-.324807E+08	-.158343E+09
-6.00	4.00	.30	28.00	.654942E+07	-.487210E+08	-.446610E+08
0.00	4.00	.30	28.00	.666043E+07	-.446610E+08	-.406009E+08
6.00	4.00	.30	28.00	.677144E+07	-.406009E+08	-.365408E+08

SWATH SIMULATION NUMBER 1 SWATH TEST CASE CASE C

TIME IN SEC	SPEED IN KNOTS	U IN M/SEC	V IN M/SEC	TURN RATE DEG/SEC	ROLL ANGLE IN DEG	PITCH ANGLE IN DEG	[illegible] ANGLE IN DEG	HEADING ANGLE IN DEG	X IN METERS	Y IN METERS	Z IN METERS	DISTANCE TRAVELED METERS	
3.00	19.90	10.12	-.00	.000	-.00	0.00	.00	-.0	30.7	.0	.2	30.7	
6.00	19.87	10.13	.00	.000	.00	0.00	-.00	.0	61.2	.0	.2	61.2	
9.00	19.62	10.10	.00	-.000	-.00	0.00	-.00	.0	91.6	.0	.2	91.6	
12.00	19.57	10.07	-.00	.000	-.00	0.00	.00	.0	121.8	.0	.2	121.8	
15.00	19.54	10.06	-.00	.000	.00	0.00	.00	.0	152.0	.0	.2	152.0	
15.000 TIME			15.00000 SEC		FWD-AFT-S		-35.00000	DEG/SEC	-5.00000			50.00000	25.00000 SEC
18.000 TIME			18.00000 SEC		FWD-AFT-F		-35.00000	DEG/SEC	-5.00000			90.00000	25.00000 SEC
18.00	19.53	10.05	-.00	-.060	.00	0.00	.00	.0	182.2	.0	.2	182.2	
21.00	19.34	9.95	-.08	.580	.22	0.00	.48	.6	212.2	.0	.2	212.2	
24.00	18.75	9.65	-.19	1.525	-.21	0.00	1.06	3.8	241.8	.6	.2	241.8	
27.00	18.06	9.30	-.28	1.857	-3.87	0.00	1.56	9.7	269.9	3.2	.2	270.0	
30.00	17.30	8.90	-.36	2.128	-6.15	0.00	2.32	15.9	296.6	8.2	.1	297.3	
33.00	16.88	8.68	-.42	2.252	-3.57	0.00	2.77	22.5	321.9	15.7	.1	323.6	
36.00	16.59	8.53	-.35	2.193	-1.51	0.00	2.38	29.5	345.6	25.9	.1	349.5	
39.00	16.40	8.43	-.33	2.249	-3.71	0.00	2.27	36.6	367.5	39.0	.1	374.9	
42.00	16.27	8.37	-.41	2.152	-5.04	0.00	2.82	43.2	387.5	54.3	.1	400.2	
45.00	16.16	8.31	-.44	2.265	-2.85	0.00	3.02	49.8	405.7	71.5	.1	425.2	
48.00	16.08	8.27	-.38	2.472	-1.89	0.00	2.64	56.8	421.5	90.7	.1	450.1	
51.00	16.04	8.25	-.38	2.265	-3.55	0.00	2.62	63.8	434.7	111.6	.1	474.9	
54.00	16.01	8.23	-.44	2.189	-4.47	0.00	3.05	70.5	445.5	133.9	.1	499.7	
57.00	15.98	8.22	-.44	2.299	-2.58	0.00	3.07	77.2	453.6	157.2	.1	524.4	
60.00	15.96	8.21	-.39	2.358	-2.35	0.00	2.74	84.2	458.9	181.3	.1	549.0	
63.00	15.95	8.20	-.40	2.256	-4.06	0.00	2.80	91.2	461.0	205.9	.1	573.7	
66.00	15.94	8.20	-.45	2.220	-4.92	0.00	3.11	97.9	460.4	230.5	.1	598.3	
69.00	15.93	8.19	-.43	2.318	-2.51	0.00	3.03	104.7	456.9	254.8	.1	622.9	
72.00	15.92	8.19	-.40	2.339	-2.75	0.00	2.78	111.7	450.4	278.5	.1	647.5	
75.00	15.92	8.19	-.41	2.250	-4.06	0.00	2.90	118.6	441.1	301.3	.1	672.1	
78.00	15.92	8.18	-.45	2.245	-3.67	0.00	3.12	125.3	429.2	322.8	.1	696.7	
81.00	15.91	8.18	-.43	2.325	-2.55	0.00	2.99	132.2	414.9	342.7	.1	721.3	
84.00	15.91	8.18	-.40	2.319	-3.05	0.00	2.82	139.2	398.2	360.8	.1	745.9	
87.00	15.92	8.18	-.42	2.249	-3.98	0.00	2.96	146.0	379.4	376.6	.1	770.4	
90.00	15.92	8.18	-.44	2.264	-3.40	0.00	3.09	152.8	359.0	390.2	.1	795.0	
93.00	15.91	8.18	-.42	2.325	-2.66	0.00	2.95	159.7	337.1	401.3	.1	819.6	
96.00	15.91	8.18	-.41	2.305	-3.27	0.00	2.85	166.7	313.9	409.6	.1	844.1	
99.00	15.91	8.18	-.47	2.252	-3.85	0.00	2.99	173.5	290.0	415.0	.1	868.7	
102.00	15.91	8.18	-.44	2.278	-3.05	0.00	3.06	180.3	265.6	417.7	.1	893.3	
105.00	15.91	8.18	-.42	2.328	-2.80	0.00	2.93	187.2	241.0	417.4	.1	917.9	
108.00	15.91	8.18	-.41	2.291	-3.41	0.00	2.88	194.2	216.7	414.0	.1	942.4	
111.00	15.91	8.18	-.43	2.258	-3.71	0.00	3.01	201.0	192.9	407.8	.1	967.0	
114.00	15.91	8.18	-.43	2.282	-3.12	0.00	3.03	207.8	170.0	398.9	.1	991.6	
117.00	15.91	8.18	-.42	2.314	-2.94	0.00	2.92	214.7	148.4	387.2	.1	1016.2	
120.00	15.91	8.18	-.42	2.283	-3.49	0.00	2.91	221.6	128.4	373.1	.1	1040.7	

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SWATH DYNAMIC SIMULATION MODEL.(U)
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SWATH SIMULATION NUMBER 1 SWATH TEST CASE CASE C

TIME IN SEC	SPEED IN KNOTS	U IN M/SEC	V IN M/SEC	TURN RATE DEG/SEC	ROLL ANGLE IN DEG	PITCH ANGLE IN DEG	DRIFT ANGLE IN DEG	HEADING ANGLE IN DEG	X IN METERS	Y IN METERS	Z IN METERS	DISTANCE TRAVELED METERS	
3.00	19.60	10.17	-.00	.000	-.00	0.00	.00	-.0	30.7	.0	.3	30.7	
6.00	19.67	10.13	.00	.000	.00	0.00	-.00	.0	61.2	.0	.2	61.2	
9.00	19.62	10.10	.00	-.000	-.00	0.00	-.00	.0	91.6	.0	.2	91.6	
12.00	19.57	10.07	-.00	.000	-.00	0.00	.00	.0	121.8	.0	.3	121.8	
15.00	19.54	10.06	-.00	.000	.00	0.00	.00	.0	152.0	.0	.2	152.0	
15.000	TIME		15.00000	SEC	RUD-AFT-S		-35.00000	DEG/SEC	-5.00000			50.00000	25.00000 SEC
18.000	TIME		18.00000	SEC	RUD-AFT-F		-35.00000	DEG/SEC	-5.00000			90.00000	25.00000 SEC
18.00	19.53	10.05	-.00	-.000	.00	0.00	.00	.0	182.2	.0	.2	182.2	
21.00	19.34	9.95	-.08	.580	.22	0.00	.48	.6	212.2	.0	.2	212.2	
24.00	18.75	9.65	-.18	1.525	-.21	0.00	1.06	3.8	241.8	.6	.2	241.8	
27.00	18.06	9.30	-.25	1.857	-3.87	0.00	1.56	9.7	269.9	3.2	.2	270.0	
30.00	17.30	8.90	-.36	2.128	-6.15	0.00	2.32	15.9	296.6	8.2	.1	297.3	
33.00	16.88	8.68	-.42	2.282	-3.57	0.00	2.77	22.5	321.9	15.7	.1	323.6	
36.00	16.59	8.53	-.35	2.393	-1.51	0.00	2.38	29.5	345.6	25.9	.1	349.5	
39.00	16.40	8.43	-.33	2.240	-3.71	0.00	2.27	36.6	367.5	39.0	.1	374.9	
42.00	16.27	8.37	-.41	2.152	-5.04	0.00	2.82	43.2	387.5	54.3	.1	400.2	
45.00	16.16	8.31	-.44	2.265	-2.83	0.00	3.02	49.8	405.7	71.5	.1	425.2	
48.00	16.08	8.27	-.38	2.372	-1.89	0.00	2.64	56.8	421.5	90.7	.1	450.1	
51.00	16.04	8.25	-.38	2.265	-3.93	0.00	2.62	63.8	434.7	111.6	.1	474.9	
54.00	16.01	8.23	-.44	2.199	-4.47	0.00	3.05	70.5	445.5	133.9	.1	499.7	
57.00	15.98	8.22	-.44	2.299	-2.58	0.00	3.07	77.2	453.6	157.2	.1	524.4	
60.00	15.96	8.21	-.39	2.358	-2.35	0.00	2.74	84.2	458.9	181.3	.1	549.0	
63.00	15.95	8.20	-.40	2.256	-4.06	0.00	2.80	91.2	461.0	205.9	.1	573.7	
66.00	15.94	8.20	-.45	2.220	-4.02	0.00	3.11	97.9	460.4	230.5	.1	598.3	
69.00	15.93	8.19	-.43	2.318	-2.51	0.00	3.03	104.7	456.9	254.8	.1	622.9	
72.00	15.92	8.19	-.40	2.339	-2.75	0.00	2.78	111.7	450.4	278.5	.1	647.5	
75.00	15.92	8.19	-.41	2.250	-4.06	0.00	2.90	118.6	441.1	301.3	.1	672.1	
78.00	15.92	8.18	-.45	2.245	-3.67	0.00	3.12	125.3	429.2	322.8	.1	696.7	
81.00	15.91	8.18	-.43	2.325	-2.55	0.00	2.99	132.2	414.9	342.7	.1	721.3	
84.00	15.91	8.18	-.40	2.319	-3.05	0.00	2.82	139.2	398.2	360.8	.1	745.8	
87.00	15.92	8.18	-.42	2.249	-3.98	0.00	2.96	146.0	379.4	376.6	.1	770.4	
90.00	15.92	8.18	-.44	2.264	-3.40	0.00	3.09	152.8	359.0	390.2	.1	795.0	
93.00	15.91	8.18	-.42	2.325	-2.66	0.00	2.95	159.7	337.1	401.3	.1	819.6	
96.00	15.91	8.18	-.41	2.305	-3.27	0.00	2.85	166.7	313.9	409.6	.1	844.1	
99.00	15.91	8.18	-.43	2.252	-3.85	0.00	2.99	173.5	290.0	415.0	.1	868.7	
102.00	15.91	8.18	-.44	2.278	-3.23	0.00	3.06	180.3	265.6	417.7	.1	893.3	
105.00	15.91	8.18	-.42	2.320	-2.80	0.00	2.93	187.2	241.0	417.4	.1	917.9	
108.00	15.91	8.18	-.41	2.291	-3.41	0.00	2.88	194.2	216.7	414.0	.1	942.4	
111.00	15.91	8.18	-.43	2.258	-3.71	0.00	3.01	201.0	192.9	407.8	.1	967.0	
114.00	15.91	8.18	-.43	2.289	-3.12	0.00	3.03	207.8	170.0	398.9	.1	991.6	
117.00	15.91	8.18	-.42	2.314	-2.94	0.00	2.92	214.7	148.4	387.2	.1	1016.2	
120.00	15.91	8.18	-.42	2.283	-3.49	0.00	2.91	221.6	128.4	373.1	.1	1040.7	

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SWATH SIMULATION NUMBER 1 SWATH TEST CODE CASE C

TIME IN SEC	SPEED IN KNOTS	PROPELLER PITCH / DIA STBD	PROPELLER PITCH / DIA PORT	PROPELLER RPM STBD	PROPELLER RPM PORT	FIN ANGLES IN DEGREES BOW STBD	FIN ANGLES IN DEGREES BOW PORT	FIN ANGLES IN DEGREES AFT STBD	FIN ANGLES IN DEGREES AFT PORT	RUDDER ANGLE IN DEG AFT STBD	RUDDER ANGLE IN DEG AFT PORT	RUDDER POSITION IN METERS BOW STBD	RUDDER POSITION IN METERS BOW PORT
3.00	19.80	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
6.00	19.67	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
9.00	19.6[illegible]	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
12.00	19.57	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
15.00	19.54	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
18.00	19.53	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00
21.00	19.44	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-15.0	-15.0	0.00	0.00
24.00	18.75	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-30.0	-30.0	0.00	0.00
27.00	18.06	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
30.00	17.50	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
33.00	16.86	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
36.00	16.59	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
39.00	16.40	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
42.00	16.27	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
45.00	16.16	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
48.00	16.08	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
51.00	16.04	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
54.00	16.01	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
57.00	15.98	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
60.00	15.96	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
63.00	15.95	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
66.00	15.94	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
69.00	15.93	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
72.00	15.92	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
75.00	15.92	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
78.00	15.92	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
81.00	15.91	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
84.00	15.91	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
87.00	15.92	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
90.00	15.92	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
93.00	15.91	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
96.00	15.91	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
99.00	15.91	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
102.00	15.91	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
105.00	15.91	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
108.00	15.91	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
111.00	15.91	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
114.00	15.91	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
117.00	15.91	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00
120.00	15.91	1.07	1.07	150.0	150.0	0.0	0.0	0.0	0.0	-35.0	-35.0	0.00	0.00

DRAFT

SWATH SIMULATION NUMBER 1 SWATH TEST [illegible] CASE C

TIME IN SEC	SPEED IN KNOTS	PROPELLER PITCH IN DEGREES STBD	PROPELLER PITCH IN DEGREES PORT	PROP RPM STBD	PROP RPM PORT	PROP X FORCE IN NEWTON	PROP Y FORCE IN NEWTON	PROP Z FORCE IN NEWTON	PROP K MOMENT NT-M	PROP M MOMENT NT-M	PROP N MOMENT NT-M
3.00	19.80	1.07	1.07	150.0	150.0	.7558E+06	0.	0.	0.	.6366E+07	0.
6.00	19.77	1.07	1.07	150.0	150.0	.8023E+06	0.	0.	0.	.6467E+07	0.
9.00	19.69	1.07	1.07	150.0	150.0	.8078E+06	0.	0.	0.	.6511E+07	0.
12.00	19.57	1.07	1.07	150.0	150.0	.8123E+05	0.	0.	0.	.6547E+07	0.
15.00	19.54	1.07	1.07	150.0	150.0	.8152E+06	0.	0.	0.	.6571E+07	0.
18.00	19.53	1.07	1.07	150.0	150.0	.8161E+06	0.	0.	0.	.6578E+07	0.
21.00	19.34	1.07	1.07	150.0	150.0	.8247E+06	0.	0.	0.	.6728E+07	0.
24.00	18.75	1.07	1.07	150.0	150.0	.8515E+06	0.	0.	0.	.7185E+07	0.
27.00	18.06	1.07	1.07	150.0	150.0	.9576E+06	0.	0.	0.	.7718E+07	0.
30.00	17.30	1.07	1.07	150.0	150.0	.1031E+07	0.	0.	0.	.8311E+07	0.
33.00	16.88	1.07	1.07	150.0	150.0	.1071E+07	0.	0.	0.	.8634E+07	0.
36.00	16.59	1.07	1.07	150.0	150.0	.1100E+07	0.	0.	0.	.8863E+07	0.
39.00	16.40	1.07	1.07	150.0	150.0	.1118E+07	0.	0.	0.	.9013E+07	0.
42.00	16.27	1.07	1.07	150.0	150.0	.1130E+07	0.	0.	0.	.9112E+07	0.
45.00	16.16	1.07	1.07	150.0	150.0	.1141E+07	0.	0.	0.	.9194E+07	0.
48.00	16.08	1.07	1.07	150.0	150.0	.1148E+07	0.	0.	0.	.9256E+07	0.
51.00	16.04	1.07	1.07	150.0	150.0	.1153E+07	0.	0.	0.	.9289E+07	0.
54.00	16.01	1.07	1.07	150.0	150.0	.1155E+07	0.	0.	0.	.9311E+07	0.
57.00	15.98	1.07	1.07	150.0	150.0	.1158E+07	0.	0.	0.	.9337E+07	0.
60.00	15.96	1.07	1.07	150.0	150.0	.1161E+07	0.	0.	0.	.9355E+07	0.
63.00	15.95	1.07	1.07	150.0	150.0	.1161E+07	0.	0.	0.	.9361E+07	0.
66.00	15.94	1.07	1.07	150.0	150.0	.1162E+07	0.	0.	0.	.9365E+07	0.
69.00	15.93	1.07	1.07	150.0	150.0	.1163E+07	0.	0.	0.	.9377E+07	0.
72.00	15.92	1.07	1.07	150.0	150.0	.1164E+07	0.	0.	0.	.9383E+07	0.
75.00	15.92	1.07	1.07	150.0	150.0	.1164E+07	0.	0.	0.	.9381E+07	0.
78.00	15.92	1.07	1.07	150.0	150.0	.1164E+07	0.	0.	0.	.9382E+07	0.
81.00	15.91	1.07	1.07	150.0	150.0	.1165E+07	0.	0.	0.	.9389E+07	0.
84.00	15.91	1.07	1.07	150.0	150.0	.1165E+07	0.	0.	0.	.9390E+07	0.
87.00	15.92	1.07	1.07	150.0	150.0	.1165E+07	0.	0.	0.	.9387E+07	0.
90.00	15.92	1.07	1.07	150.0	150.0	.1165E+07	0.	0.	0.	.9388E+07	0.
93.00	15.91	1.07	1.07	150.0	150.0	.1165E+07	0.	0.	0.	.9392E+07	0.
96.00	15.91	1.07	1.07	150.0	150.0	.1165E+07	0.	0.	0.	.9392E+07	0.
99.00	15.91	1.07	1.07	150.0	150.0	.1165E+07	0.	0.	0.	.9389E+07	0.
102.00	15.91	1.07	1.07	150.0	150.0	.1165E+07	0.	0.	0.	.9390E+07	0.
105.00	15.91	1.07	1.07	150.0	150.0	.1165E+07	0.	0.	0.	.9393E+07	0.
108.00	15.91	1.07	1.07	150.0	150.0	.1165E+07	0.	0.	0.	.9392E+07	0.
111.00	15.91	1.07	1.07	150.0	150.0	.1165E+07	0.	0.	0.	.9390E+07	0.
114.00	15.91	1.07	1.07	150.0	150.0	.1165E+07	0.	0.	0.	.9391E+07	0.
117.00	15.91	1.07	1.07	150.0	150.0	.1165E+07	0.	0.	0.	.9393E+07	0.
120.00	15.91	1.07	1.07	150.0	150.0	.1165E+07	0.	0.	0.	.9391E+07	0.

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SWATH SIMULATION NUMBER 1 SWATH [illegible] CASE C

TIME IN SEC	SPEED IN KNOTS	FWD RUDDER POSITION IN METERS STBD	FWD RUDDER POSITION IN METERS PORT	AFT RUDDER ANGLES IN DEGREES, STBD	AFT RUDDER ANGLES IN DEGREES, PORT	RUDDER Y FORCE IN NEWTON	RUDDER Y FORCE IN NEWTON	RUDDER Z FORCE IN NEWTON	RUDDER K MOMENT NT-M	RUDDER M MOMENT NT-M	RUDDER N MOMENT NT-M
3.00	[illegible]	0.00	0.00	0.00	0.00	-.3105E-09	-.4586E-08	0.	.1786E-07	-.3783E-08	.5406E-07
6.00	[illegible]	0.00	0.00	0.00	0.00	-.4794E-09	-.1079E-08	0.	.5752E-08	-.1863E-08	.8053E-07
9.00	[illegible]	0.00	0.00	0.00	0.00	-.7558E-09	-.1679E-08	0.	.9595E-08	-.1397E-06	.9595E-07
12.00	19.57	0.00	0.00	0.00	0.00	-.3006E-09	-.1443E-08	0.	.1024E-07	-.1164E-08	.3078E-07
15.00	19.54	0.00	0.00	0.00	0.00	-.5555E-10	-.1918E-08	0.	.8632E-08	-.2329E-09	.6506E-07
18.00	19.53	0.00	0.00	0.00	0.00	-.1860E-09	-.3119E-08	0.	.9598E-08	-.6986E-09	.6143E-07
21.00	19.34	0.00	0.00	-15.00	-15.00	-.2112E+06	-.1957E+07	0.	.5748E+07	-.8198E+06	.3067E+08
24.00	18.75	0.00	0.00	-30.00	-30.00	-.5346E+06	-.1841E+07	0.	.8958E+07	-.2080E+07	.5507E+08
27.00	18.06	0.00	0.00	-35.00	-35.00	-.6004E+06	-.1676E+07	0.	.8551E+07	-.2665E+07	.5572E+08
30.00	17.30	0.00	0.00	-35.00	-35.00	-.6387E+06	-.1602E+07	0.	.7969E+07	-.2510E+07	.5325E+08
33.00	16.88	0.00	0.00	-35.00	-35.00	-.6172E+06	-.1565E+07	0.	.7668E+07	-.2426E+07	.5012E+08
36.00	16.59	0.00	0.00	-35.00	-35.00	-.6022E+06	-.1539E+07	0.	.7457E+07	-.2366E+07	.4789E+08
39.00	16.40	0.00	0.00	-35.00	-35.00	-.5915E+06	-.1520E+07	0.	.7308E+07	-.2327E+07	.4636E+08
42.00	16.27	0.00	0.00	-35.00	-35.00	-.5832E+06	-.1504E+07	0.	.7194E+07	-.2301E+07	.4525E+08
45.00	16.16	0.00	0.00	-35.00	-35.00	-.5794E+06	-.1499E+07	0.	.7138E+07	-.2279E+07	.4458E+08
48.00	16.08	0.00	0.00	-35.00	-35.00	-.5752E+06	-.1492E+07	0.	.7079E+07	-.2263E+07	.4396E+08
51.00	16.04	0.00	0.00	-35.00	-35.00	-.5718E+06	-.1485E+07	0.	.7034E+07	-.2254E+07	.4355E+08
54.00	16.01	0.00	0.00	-35.00	-35.00	-.5704E+06	-.1482E+07	0.	.7015E+07	-.2249E+07	.4334E+08
57.00	15.98	0.00	0.00	-35.00	-35.00	-.5692E+06	-.1481E+07	0.	.6997E+07	-.2242E+07	.4313E+08
60.00	15.96	0.00	0.00	-35.00	-35.00	-.5683E+06	-.1479E+07	0.	.6983E+07	-.2237E+07	.4294E+08
63.00	15.95	0.00	0.00	-35.00	-35.00	-.5670E+06	-.1476E+07	0.	.6967E+07	-.2236E+07	.4284E+08
66.00	15.94	0.00	0.00	-35.00	-35.00	-.5667E+06	-.1476E+07	0.	.6962E+07	-.2235E+07	.4280E+08
69.00	15.93	0.00	0.00	-35.00	-35.00	-.5668E+06	-.1477E+07	0.	.6962E+07	-.2232E+07	.4275E+08
72.00	15.92	0.00	0.00	-35.00	-35.00	-.5660E+06	-.1475E+07	0.	.6952E+07	-.2230E+07	.4266E+08
75.00	15.92	0.00	0.00	-35.00	-35.00	-.5656E+06	-.1474E+07	0.	.6947E+07	-.2230E+07	.4264E+08
78.00	15.92	0.00	0.00	-35.00	-35.00	-.5658E+06	-.1474E+07	0.	.6949E+07	-.2230E+07	.4265E+08
81.00	15.91	0.00	0.00	-35.00	-35.00	-.5657E+06	-.1475E+07	0.	.6948E+07	-.2228E+07	.4261E+08
84.00	15.91	0.00	0.00	-35.00	-35.00	-.5655E+06	-.1474E+07	0.	.6945E+07	-.2228E+07	.4259E+08
87.00	15.92	0.00	0.00	-35.00	-35.00	-.5652E+06	-.1473E+07	0.	.6941E+07	-.2229E+07	.4258E+08
90.00	15.92	0.00	0.00	-35.00	-35.00	-.5655E+06	-.1474E+07	0.	.6945E+07	-.2229E+07	.4260E+08
93.00	15.91	0.00	0.00	-35.00	-35.00	-.5655E+06	-.1474E+07	0.	.6945E+07	-.2227E+07	.4258E+08
96.00	15.91	0.00	0.00	-35.00	-35.00	-.5652E+06	-.1473E+07	0.	.6941E+07	-.2228E+07	.4256E+08
99.00	15.91	0.00	0.00	-35.00	-35.00	-.5652E+06	-.1473E+07	0.	.6941E+07	-.2228E+07	.4257E+08
102.00	15.91	0.00	0.00	-35.00	-35.00	-.5654E+06	-.1474E+07	0.	.6944E+07	-.2229E+07	.4258E+08
105.00	15.91	0.00	0.00	-35.00	-35.00	-.5654E+06	-.1474E+07	0.	.6943E+07	-.2227E+07	.4257E+08
108.00	15.91	0.00	0.00	-35.00	-35.00	-.5652E+06	-.1473E+07	0.	.6941E+07	-.2228E+07	.4256E+08
111.00	15.91	0.00	0.00	-35.00	-35.00	-.5652E+06	-.1473E+07	0.	.6941E+07	-.2228E+07	.4257E+08
114.00	15.91	0.00	0.00	-35.00	-35.00	-.5654E+06	-.1474E+07	0.	.6943E+07	-.2228E+07	.4258E+08
117.00	15.91	0.00	0.00	-35.00	-35.00	-.5653E+06	-.1474E+07	0.	.6942E+07	-.2227E+07	.4256E+08
120.00	15.91	0.00	0.00	-35.00	-35.00	-.5651E+06	-.1473E+07	0.	.6941E+07	-.2228E+07	.4256E+08

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SWATH SIMULATION NUMBER 1 SWATH TEST 6 DOF CASE C

TIME IN SEC	SPEED IN KNOTS	BOW FIN ANGLES IN DEGREES STBD	BOW FIN ANGLES IN DEGREES PORT	AFT FIN ANGLES IN DEGREES STBD	AFT FIN ANGLES IN DEGREES PORT	FIN Y FORCE IN NEWTON	FIN Y FORCE IN NEWTON	FIN Z FORCE IN NEWTON	FIN K MOMENT NT-M	FIN M MOMENT NT-M	FIN N MOMENT NT-M
3.00	19.60	0.00	0.00	0.00	0.00	-.3110E+03	0.	.2179E+04	-.7957E-07	.3100E+05	-.1127E-07
6.00	19.67	0.00	0.00	0.00	0.00	-.5071E+03	0.	.6430E+04	.2072E-07	.3153E+05	.2896E-08
9.00	19.62	0.00	0.00	0.00	0.00	-.7715E+03	0.	-.5459E+04	.5320E-07	-.9013E+05	-.7451E-08
12.00	19.57	0.00	0.00	0.00	0.00	-.2024E+03	0.	.1421E+04	-.2572E-07	.2021E+05	-.4216E-08
15.00	19.54	0.00	0.00	0.00	0.00	-.2864E+03	0.	.2005E+04	-.1167E-07	.2853E+05	-.1655E-08
18.00	19.53	0.00	0.00	0.00	0.00	-.3074E+03	0.	-.2161E+04	.9197E-08	-.3569E+05	-.1302E-08
21.00	19.34	0.00	0.00	0.00	0.00	-.8026E+03	0.	.1707E+04	-.4416E+05	.1181E+05	-.1751E+04
24.00	18.75	0.00	0.00	0.00	0.00	-.4701E+04	0.	.2352E+04	.2768E+06	.6700E+04	.2082E+04
27.00	18.06	0.00	0.00	0.00	0.00	-.7366E+04	0.	.2511E+05	.4868E+06	.6536E+06	.1917E+05
30.00	17.30	0.00	0.00	0.00	0.00	-.4747E+04	0.	.3172E+05	-.3960E+05	.9359E+06	-.2878E+04
33.00	16.88	0.00	0.00	0.00	0.00	-.6227E+04	0.	.2209E+05	-.4059E+06	.5812E+06	-.1878E+05
36.00	16.59	0.00	0.00	0.00	0.00	-.1276E+04	0.	.6889E+04	.3505E+05	.2242E+06	.2182E+04
39.00	16.40	0.00	0.00	0.00	0.00	-.4650E+04	0.	.2042E+05	.3025E+06	.5746E+06	.1724E+05
42.00	16.27	0.00	0.00	0.00	0.00	-.3901E+04	0.	.2607E+05	-.9235E+05	.7484E+06	-.6366E+04
45.00	16.16	0.00	0.00	0.00	0.00	-.4343E+04	0.	.1464E+05	-.2691E+06	.4125E+06	-.1331E+05
48.00	16.08	0.00	0.00	0.00	0.00	-.1958E+04	0.	.1104E+05	.1010E+06	.3078E+06	.8938E+04
51.00	16.04	0.00	0.00	0.00	0.00	-.3485E+04	0.	.1980E+05	.2103E+06	.5827E+06	.1644E+05
54.00	16.01	0.00	0.00	0.00	0.00	-.3686E+04	0.	.2350E+05	-.1295E+06	.6678E+06	-.1607E+05
57.00	15.98	0.00	0.00	0.00	0.00	-.2954E+04	0.	.1418E+05	-.1787E+06	.3969E+06	-.1376E+05
60.00	15.96	0.00	0.00	0.00	0.00	-.2267E+04	0.	.1199E+05	.1283E+06	.3554E+06	.1081E+05
63.00	15.95	0.00	0.00	0.00	0.00	-.3499E+04	0.	.2171E+05	.1302E+06	.6187E+06	.9407E+04
66.00	15.94	0.00	0.00	0.00	0.00	-.3404E+04	0.	.2080E+05	-.1418E+06	.5977E+06	-.1141E+05
69.00	15.93	0.00	0.00	0.00	0.00	-.2364E+04	0.	.1364E+05	-.1067E+06	.3888E+06	-.9384E+04
72.00	15.92	0.00	0.00	0.00	0.00	-.2606E+04	0.	.1464E+05	.1302E+06	.4230E+06	.1067E+05
75.00	15.92	0.00	0.00	0.00	0.90	-.3240E+04	0.	.2103E+05	.6660E+05	.6088E+06	.3716E+04
78.00	15.92	0.00	0.00	0.00	0.00	-.3216E+04	0.	.1959E+05	-.1354E+06	.5560E+06	-.1121E+05
81.00	15.91	0.00	0.00	0.00	0.00	-.2168E+04	0.	.1361E+05	-.5076E+05	.3937E+06	-.3914E+04
84.00	15.91	0.00	0.00	0.00	0.00	-.2768E+04	0.	.1611E+05	.1169E+06	.4668E+06	.9098E+04
87.00	15.92	0.00	0.00	0.00	0.00	-.3123E+04	0.	.2095E+05	.1877E+05	.6017E+06	.3336E+03
90.00	15.92	0.00	0.00	0.00	0.00	-.2964E+04	0.	.1794E+05	-.1168E+06	.5145E+06	-.9631E+04
93.00	15.91	0.00	0.00	0.00	0.00	-.2216E+04	0.	.1433E+05	-.1102E+05	.4130E+06	-.1101E+04
96.00	15.91	0.00	0.00	0.00	0.00	-.2847E+04	0.	.1722E+05	.9510E+05	.4987E+06	.6506E+04
99.00	15.91	0.00	0.00	0.00	0.00	-.3076E+04	0.	.2021E+05	-.1367E+05	.5816E+06	-.1381E+04
102.00	15.91	0.00	0.00	0.00	0.00	-.2709E+04	0.	.1721E+05	-.9305E+05	.4925E+06	-.7570E+04
105.00	15.91	0.00	0.00	0.00	0.00	-.2704E+04	0.	.1485E+05	.1463E+05	.4308E+06	.3812E+03
108.00	15.91	0.00	0.00	0.00	0.00	-.2865E+04	0.	.1803E+05	.7033E+05	.5205E+06	.4565E+04
111.00	15.91	0.00	0.00	0.00	0.00	-.2937E+04	0.	.1951E+05	-.3302E+05	.5615E+06	-.2425E+04
114.00	15.91	0.00	0.00	0.00	0.00	-.2625E+04	0.	.1660E+05	-.6838E+05	.4773E+06	-.5305E+04
117.00	15.91	0.00	0.00	0.00	0.00	-.2405E+04	0.	.1564E+05	.2840E+05	.4527E+06	.1141E+04
120.00	15.91	0.00	0.00	0.00	0.00	-.2820E+04	0.	.1835E+05	.4655E+05	.5305E+06	.2350E+04

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ALL RUNS COMPLETED INTERMEDIATE PRINT FOLLOWS.
 TIME    U      V      W     PHI   THETA  BETA            FIN      RUDDER      HULL        AERO       BUOYANCY      RATE      PROPULSION
  0.0  10.30   0.00   0.00   0.00   0.00  -0.00   X 0.              -.9313E-09 -.8730E+06 0.           0.           0.            .7708E+06
                                                  Y 0.               .3725E-08 0.          0.           0.           0.           0.
                                                  Z 0.              0.           .5068E+06 0.           0.           0.           0.
                                                  K 0.              -.2960E-07 0.          0.           0.           0.           0.
                                                  M 0.              -.3725E-08 -.7037E+07 0.           0.           0.            .6213E+07
                                                  N 0.              -.2384E-06 0.          0.           0.           0.           0.

 TIME    U      V      W     PHI   THETA  BETA            FIN      RUDDER      HULL        AERO       BUOYANCY      RATE      PROPULSION
  3.0  10.20   -.00    .12    .00   0.00    .00   X -.5918E+04 -.4554E-10 -.8684E+06 0.           0.           0.            .7892E+06
                                                  Y 0.         -.9716E-09   .1672E-07 0.           0.           0.           0.
                                                  Z -.4537E+05 0.            .4938E+06 0.          -.6717E+06   0.           0.
                                                  K -.1118E-07   .4858E-08 -.9113E-07 0.          -.4228E-06   0.           0.
                                                  M -.7451E+06 -.1745E-09 -.6951E+07 0.            .1458E+06   0.            .6361E+07
                                                  N  .1397E-08   .4664E-07   .6076E-07 0.          0.           0.           0.

 TIME    U      V      W     PHI   THETA  BETA            FIN      RUDDER      HULL        AERO       BUOYANCY      RATE      PROPULSION
  6.0  10.13    .00   -.10    .00   0.00   -.00   X -.4853E+04 -.1815E-09 -.8472E+06 0.           0.           0.            .8019E+06
                                                  Y 0.           .1694E-08 -.6519E-08 0.           0.           0.           0.
                                                  Z  .3657E+05 0.            .4850E+06 0.          -.6067E+06   0.           0.
                                                  K  .1723E-07   .2903E-08   .3725E-07 0.          -.1698E-06   0.           0.
                                                  M  .5230E+06 -.6983E-05 -.6786E+07 0.            .1317E+06   0.            .6463E+07
                                                  N  .2154E-08 -.3484E-07 -.4768E-06 0.          0.           0.           0.

 TIME    U      V      W     PHI   THETA  BETA            FIN      RUDDER      HULL        AERO       BUOYANCY      RATE      PROPULSION
  9.0  10.10   -.00    .01   -.00   0.00    .00   X -.6401E+03 -.2373E-09 -.8275E+06 0.           0.           0.            .8081E+06
                                                  Y 0.         -.1186E-08 -.7451E-08 0.           0.           0.           0.
                                                  Z -.4591E+04 0.            .4806E+06 0.          -.2931E+06   0.           0.
                                                  K  .6345E-08 -.7593E-08   .1192E-06 0.           .5620E-06   0.           0.
                                                  M -.7466E+05 -.9317E-09 -.6545E+07 0.            .6361E+05   0.            .6514E+07
                                                  N -.8677E-09 -.5695E-07   .9537E-06 0.          0.           0.           0.

 TIME    U      V      W     PHI   THETA  BETA            FIN      RUDDER      HULL        AERO       BUOYANCY      RATE      PROPULSION
 12.0  10.08   -.00    .04   -.00   0.00    .00   X -.2046E+04 -.6032E-10 -.8301E+06 0.           0.           0.            .8122E+06
                                                  Y 0.           .1206E-08 -.1490E-07 0.           0.           0.           0.
                                                  Z -.1475E+05 0.            .4776E+06 0.          -.5616E+06   0.           0.
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[illegible]	-.19[illegible]E-07	0.	.17[illegible]E-0[illegible]	0.	[illegible]	0.	0.
M	-.2932E+06	-.2320E-0[illegible]	-.6659E+07	0.	.1219E+06	0.	.6546E+07
N	.1[illegible]79E-08	.2316E-07	-.5537E-06	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
15.0	10.0[illegible]	-.00	-.06	.00	0.00	.0[illegible]	X	-.1[illegible]E+04	0.	-.7249E+06	0.	0.	0.	.8151E+06
							Y	0.	-.9[illegible]1E-0[illegible]	.1097E-07	0.	0.	0.	0.
							Z	.1415E+05	0.	.4759E+06	0.	-.5069E+06	0.	0.
							K	-.5[illegible]E-0[illegible]	.5[illegible]E-0[illegible]	-.6543E-07	0.	-.3104E-06	0.	0.
							M	.2017E+06	0.	-.6606E+07	0.	.1109E+06	0.	.6569E+07
							N	-.7776E-09	.3847E-07	-.4362E-07	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
18.0	10.65	-.00	.01	.00	0.00	.00	X	-.4705E+03	-.2987E-05	-.7199E+06	0.	0.	0.	.8162E+06
							Y	0.	-.2868E-06	.1369E-07	0.	0.	0.	0.
							Z	-.3315E+04	0.	.4751E+06	0.	-.4074E+06	0.	0.
							K	.1688E-08	.1147E-07	-.1107E-06	0.	-.1236E-06	0.	0.
							M	-.5475E+05	-.1165E-0[illegible]	-.6573E+07	0.	.8842E+05	0.	.6578E+07
							N	-.2398E-09	.9942E-07	-.7206E-07	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
21.0	9.95	-.08	.01	.00	0.00	.01	X	-.1020E+04	-.2116E+06	-.7936E+06	0.	0.	0.	.8347E+06
							Y	0.	-.1059E+07	.7106E+06	0.	0.	0.	0.
							Z	-.3973E+04	0.	.4625E+06	0.	-.5052E+06	0.	0.
							K	-.5654E+05	.5758E+07	-.7021E+07	0.	-.1225E+07	0.	0.
							M	-.7526E+05	-.8197E+06	-.6363E+07	0.	.1097E+06	0.	.6728E+07
							N	.4274E+04	.3073E+08	-.1246E+08	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
24.0	9.68	-.11	-.02	-.00	0.00	.02	X	-.3968E+04	-.5370E+06	-.7222E+06	0.	0.	0.	.8863E+06
							Y	0.	-.1849E+07	.1848E+07	0.	0.	0.	0.
							Z	.8278E+04	0.	.4284E+06	0.	-.4462E+06	0.	0.
							K	.2718E+06	.9010E+07	-.1890E+08	0.	.1029E+07	0.	0.
							M	.1090E+06	-.2088E+07	-.5794E+07	0.	.9686E+05	0.	.7143E+07
							N	.7915E+04	.5540E+08	-.3744E+08	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
27.0	9.22	-.25	-.03	-.07	0.00	.03	X	-.7121E+04	-.6717E+06	-.6395E+06	0.	0.	0.	.9724E+06
							Y	0.	-.1661E+07	.2400E+07	0.	0.	0.	0.
							Z	.2150E+05	0.	.3755E+06	0.	-.3138E+06	0.	0.
							K	.4700E+06	.8430E+07	-.2562E+08	0.	.1723E+08	0.	0.
							M	.5877E+06	-.2634E+07	-.5139E+07	0.	.6812E+05	0.	.7838E+07
							N	.1639E+05	.5808E+08	-.5729E+08	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
30.0	8.[illegible]0	-.36	-.04	-.11	0.00	.04	X	-.4750E+04	-.6387E+06	-.5993E+06	0.	0.	0.	.1031E+07
							Y	0.	-.1602E+07	.2458E+07	0.	0.	0.	0.
							Z	.3174E+05	0.	.3417E+06	0.	-.2772E+06	0.	0.
							K	-.4056E+05	.7969E+07	-.2531E+08	0.	.2821E+08	0.	0.
							M	.9365E+06	-.2510E+07	-.4817E+07	0.	.6018E+05	0.	.8311E+07
							N	-.2924E+04	.5330E+08	-.5316E+08	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
33.0	8.68	-.42	-.03	-.06	0.00	.05	X	-.6234E+04	-.6172E+06	-.5752E+06	0.	0.	0.	.1071E+07
							Y	0.	-.1565E+07	.2590E+07	0.	0.	0.	0.
							Z	.2210E+05	0.	.3197E+06	0.	-.2792E+06	0.	0.
							K	-.4064E+06	.7665E+07	-.2492E+08	0.	.1629E+08	0.	0.
							M	.5810E+06	-.2426E+07	-.4623E+07	0.	.6050E+05	0.	.8634E+07
							N	-.1878E+05	.5012E+08	-.4696E+08	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
36.0	8.53	-.35	-.01	-.03	0.00	.04	X	-.1972E+04	-.6022E+06	-.5673E+06	0.	0.	0.	.1100E+07
							Y	0.	-.153[illegible]E+07	.2522E+07	0.	0.	0.	0.
							Z	.6[illegible]5E+04	0.	.3052E+06	0.	-.2852E+06	0.	0.
							K	.3591E+05	.7457E+07	-.2414E+08	0.	.6899E+07	0.	0.
							M	.2209E+06	-.2366E+07	-.4559E+07	0.	.6190E+05	0.	.8863E+07

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 N  [illegible]    [illegible]  -.47[illegible]4+08 0.          0.          0.          0.

TIME   U     V     W     PHI   THETA  BETA        FIN        RUDDER       HULL      AERO     BUOYANCY      RATE      PROPULSION
39.0  8.4[illegible] -.4[illegible] -.[illegible] -.07 [illegible]  .04   X -.4[illegible]E+04 -.5[illegible]E+06 -.5515E+06 0.   0.           0.          .1114E+07
                                              Y 0.          -.15[illegible]E+07  .2357E+07 0.   0.           0.          0.
                                              Z  .2660E+05 0.                 .2459E+06 0.  -.2667E+06  0.          0.
                                              K  .5629E+06  .7308E+07 -.2284E+08 0.    .1698E+08  0.          0.
                                              M  .5761E+06 -.2327E+07 -.4513E+07 0.    .5799E+05  0.           .9013E+07
                                              N  .1729E+05  .4636E+08 -.5021E+08 0.   0.           0.          0.

TIME   U     V     W     PHI   THETA  BETA        FIN        RUDDER       HULL      AERO     BUOYANCY      RATE      PROPULSION
42.0  8.37  -.41  -.03  -.05  0.00   .05   X -.3902E+04 -.5831E+06 -.5568E+06 0.   0.           0.          .1130E+07
                                              Y 0.          -.1504E+07  .2378E+07 0.   0.           0.          0.
                                              Z  .2[illegible]E+05 0.                 .2894E+06 0.  -.2179E+06  0.          0.
                                              K -.9[illegible]E+05  .7199E+07 -.2232E+08 0.    .2309E+08  0.          0.
                                              M  .7491E+06 -.2301E+07 -.4479E+07 0.    .4731E+05  0.           .9112E+07
                                              N -.6429E+04  .4621E+08 -.4539E+08 0.   0.           0.          0.

TIME   U     V     W     PHI   THETA  BETA        FIN        RUDDER       HULL      AERO     BUOYANCY      RATE      PROPULSION
45.0  8.31  -.44  -.01  -.05  0.00   .05   X -.4346E+04 -.5734E+06 -.5548E+06 0.   0.           0.          .1141E+07
                                              Y 0.          -.1499E+07  .2487E+07 0.   0.           0.          0.
                                              Z  .1463E+05 0.                 .2843E+06 0.  -.2642E+06  0.          0.
                                              K -.2693E+06  .7139E+07 -.2275E+08 0.    .1292E+08  0.          0.
                                              M  .4121E+06 -.2279E+07 -.4459E+07 0.    .5734E+05  0.           .9194E+07
                                              N -.1330E+05  .4458E+08 -.4103E+08 0.   0.           0.          0.

TIME   U     V     W     PHI   THETA  BETA        FIN        RUDDER       HULL      AERO     BUOYANCY      RATE      PROPULSION
48.0  8.27  -.38  -.02  -.03  0.00   .05   X -.1999E+04 -.5752E+06 -.5523E+06 0.   0.           0.          .1148E+07
                                              Y 0.          -.1492E+07  .2443E+07 0.   0.           0.          0.
                                              Z  .1104E+05 0.                 .2808E+06 0.  -.2612E+06  0.          0.
                                              K  .1017E+06  .7079E+07 -.2267E+08 0.    .8608E+07  0.          0.
                                              M  .3076E+06 -.2263E+07 -.4440E+07 0.    .5670E+05  0.           .9256E+07
                                              N  .9009E+04  .4396E+08 -.4415E+08 0.   0.           0.          0.

TIME   U     V     W     PHI   THETA  BETA        FIN        RUDDER       HULL      AERO     BUOYANCY      RATE      PROPULSION
51.0  8.25  -.38  -.03  -.07  0.00   .05   X -.3487E+04 -.5718E+06 -.5504E+06 0.   0.           0.          .1153E+07
                                              Y 0.          -.1485E+07  .2350E+07 0.   0.           0.          0.
                                              Z  .1981E+05 0.                 .2788E+06 0.  -.2307E+06  0.          0.
                                              K  .2104E+06  .7034E+07 -.2195E+08 0.    .1798E+08  0.          0.
                                              M  .5872E+06 -.2254E+07 -.4426E+07 0.    .5008E+05  0.           .9289E+07
                                              N  .1644E+05  .4355E+08 -.4657E+08 0.   0.           0.          0.

TIME   U     V     W     PHI   THETA  BETA        FIN        RUDDER       HULL      AERO     BUOYANCY      RATE      PROPULSION
54.0  8.23  -.44  -.03  -.03  0.00   .05   X -.3698E+04 -.5704E+06 -.5496E+06 0.   0.           0.          .1155E+07
                                              Y 0.          -.1482E+07  .2400E+07 0.   0.           0.          0.
                                              Z  .2351E+05 0.                 .2773E+06 0.  -.2312E+06  0.          0.
                                              K -.1302E+06  .7015E+07 -.2189E+08 0.    .2045E+08  0.          0.
                                              M  .6678E+06 -.2249E+07 -.4419E+07 0.    .5020E+05  0.           .9311E+07
                                              N -.1013E+05  .4334E+08 -.4268E+08 0.   0.           0.          0.

TIME   U     V     W     PHI   THETA  BETA        FIN        RUDDER       HULL      AERO     BUOYANCY      RATE      PROPULSION
57.0  8.22  -.44  -.02  -.04  0.00   .05   X -.2954E+04 -.5692E+06 -.5491E+06 0.   0.           0.          .1158E+07
                                              Y 0.          -.1481E+07  .2476E+07 0.   0.           0.          0.
                                              Z  .1417E+05 0.                 .2757E+06 0.  -.2455E+06  0.          0.
                                              K -.1727E+06  .6997E+07 -.2239E+08 0.    .1175E+08  0.          0.
                                              M  .3965E+06 -.2242E+07 -.4414E+07 0.    .5329E+05  0.           .9337E+07
                                              N -.1375E+05  .4313E+08 -.4043E+08 0.   0.           0.          0.

TIME   U     V     W     PHI   THETA  BETA        FIN        RUDDER       HULL      AERO     BUOYANCY      RATE      PROPULSION
60.0  8.21  -.3[illegible] -.02  -.04  0.00   .05   X -.2268E+04 -.5683E+06 -.5489E+06 0.   0.           0.          .1161E+07
                                              Y 0.          -.1479E+07  .2424E+07 0.   0.           0.          0.
                                              Z  .1197E+05 0.                 .2748E+06 0.  -.2528E+06  0.          0.
                                              K  .1288E+06  .6983E+07 -.2230E+08 0.    .1973E+08  0.          0.
                                              M  .3551E+06 -.2237E+07 -.4413E+07 0.    .5489E+05  0.           .9355E+07
                                              N  .1087E+05  .4297E+08 -.4380E+08 0.   0.           0.          0.
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TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
63.0	8.20	-.40	-.03	-.07	[illegible]	.05	X	[illegible]	[illegible]	-.5463E+06	0.	0.	0.	.1161E+07
							Y	0.	-.1472E+07	.2366E+07	0.	0.	0.	0.
							Z	.2174E+05	0.	.2745E+06	0.	-.2278E+06	0.	0.
							K	.1401E+06	.6967E+07	-.2179E+08	0.	.1857E+08	0.	0.
							M	.6154E+06	-.2236E+07	-.4402E+07	0.	.4945E+05	0.	.9361E+07
							N	.9377E+04	.4283E+08	-.4501E+08	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
66.0	8.20	-.45	-.04	-.07	0.00	.05	X	-.3404E+04	-.5667E+06	-.5482E+06	0.	0.	0.	.1162E+07
							Y	0.	-.1476E+07	.2421E+07	0.	0.	0.	0.
							Z	.2278E+05	0.	.2740E+06	0.	-.2263E+06	0.	0.
							K	-.1423E+06	.6962E+07	-.2189E+08	0.	.1839E+08	0.	0.
							M	.5973E+06	-.2237E+07	-.4408E+07	0.	.4912E+05	0.	.9365E+07
							N	-.1146E+05	.4288E+08	-.4170E+08	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
69.0	8.19	-.43	-.02	-.04	0.00	.05	X	-.2363E+04	-.5668E+06	-.5486E+06	0.	0.	0.	.1163E+07
							Y	0.	-.1477E+07	.2466E+07	0.	0.	0.	0.
							Z	.1364E+05	0.	.2734E+06	0.	-.2507E+06	0.	0.
							K	-.1066E+06	.6962E+07	-.2230E+08	0.	.1144E+08	0.	0.
							M	.3826E+06	-.2232E+07	-.4410E+07	0.	.5442E+05	0.	.9377E+07
							N	-.9374E+04	.4275E+08	-.4086E+08	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
72.0	8.19	-.40	-.02	-.05	0.00	.05	X	-.2607E+04	-.5660E+06	-.5483E+06	0.	0.	0.	.1164E+07
							Y	0.	-.1475E+07	.2412E+07	0.	0.	0.	0.
							Z	.1464E+05	0.	.2732E+06	0.	-.2414E+06	0.	0.
							K	.1306E+06	.6952E+07	-.2213E+08	0.	.1254E+08	0.	0.
							M	.4230E+06	-.2239E+07	-.4408E+07	0.	.5240E+05	0.	.9383E+07
							N	.1070E+05	.4266E+08	-.4387E+08	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
75.0	8.19	-.41	-.03	-.07	0.00	.05	X	-.3241E+04	-.5656E+06	-.5480E+06	0.	0.	0.	.1164E+07
							Y	0.	-.1474E+07	.2380E+07	0.	0.	0.	0.
							Z	.2104E+05	0.	.2732E+06	0.	-.2266E+06	0.	0.
							K	.6643E+05	.6947E+07	-.2177E+08	0.	.1857E+08	0.	0.
							M	.6091E+06	-.2230E+07	-.4406E+07	0.	.4919E+05	0.	.9381E+07
							N	.3699E+04	.4264E+08	-.4413E+08	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
78.0	8.18	-.45	-.03	-.06	0.00	.05	X	-.3217E+04	-.5658E+06	-.5481E+06	0.	0.	0.	.1164E+07
							Y	0.	-.1474E+07	.2433E+07	0.	0.	0.	0.
							Z	.1958E+05	0.	.2730E+06	0.	-.2329E+06	0.	0.
							K	-.1358E+06	.6949E+07	-.2196E+08	0.	.1675E+08	0.	0.
							M	.5559E+06	-.2230E+07	-.4407E+07	0.	.5056E+05	0.	.9382E+07
							N	-.1124E+05	.4265E+08	-.4135E+08	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
81.0	8.18	-.43	-.02	-.04	0.00	.05	X	-.2165E+04	-.5657E+06	-.5483E+06	0.	0.	0.	.1165E+07
							Y	0.	-.1475E+07	.2454E+07	0.	0.	0.	0.
							Z	.1399E+05	0.	.2727E+06	0.	-.2445E+06	0.	0.
							K	-.5066E+05	.6948E+07	-.2224E+08	0.	.1165E+08	0.	0.
							M	.3934E+06	-.2228E+07	-.4408E+07	0.	.5308E+05	0.	.9389E+07
							N	-.3995E+04	.4261E+08	-.4146E+08	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
84.0	8.18	-.40	-.02	-.05	0.00	.05	X	-.2770E+04	-.5655E+06	-.5481E+06	0.	0.	0.	.1165E+07
							Y	0.	-.1474E+07	.2404E+07	0.	0.	0.	0.
							Z	.1612E+05	0.	.2727E+06	0.	-.2404E+06	0.	0.
							K	.1171E+06	.6945E+07	-.2203E+08	0.	.1396E+08	0.	0.
							M	.4670E+06	-.2228E+07	-.4407E+07	0.	.5217E+05	0.	.9390E+07
							N	.9121E+04	.4255E+08	-.4388E+08	0.	0.	0.	0.

TIME	U	V	W	PHI	THETA	BETA		FIN	RUDDER	HULL	AERO	BUOYANCY	RATE	PROPULSION
87.0	8.18	-.42	-.03	-.07	0.00	.05	X	-.3124E+04	-.5652E+06	-.5479E+06	0.	0.	0.	.1165E+07

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                                                      Y 0.          -.147[illegible]    .2[illegible]+07 0.           0.            0.            0.
                                                      Z .[illegible]+05  0.             .27[illegible]+06 0.       -.2[illegible]+06 0.      0.
                                                      K .1[illegible]+05  .694[illegible]+07 -.21[illegible]+0[illegible] 0.   .1[illegible]+0[illegible] 0.   0.
                                                      M .60[illegible]+06 -.222[illegible]+07 -.4406[illegible]+07 0.  .4[illegible]+05 0.   .9387F+07
                                                      N .3[illegible]+03  .425[illegible]   -.4343[illegible]+08 0.   0.            0.            0.

TIME   U     V     W     PHI   THETA  BETA      FIN           RUDDER        HULL          AERO    BUOYANCY      RATE    PROPULSION
90.0   8.18  -.44  -.0[illegible]  -.0[illegible]  [illegible]  .05   X -.2[illegible]4E+04 -.5[illegible]E+06 -.5461E+06 0.        0.            0.       .1165E+07
                                                      Y 0.          -.1474E+07    .24[illegible]+07 0.         0.            0.       0.
                                                      Z .17[illegible]+05 0.            .2727E+06 0.        -.2[illegible]+06 0.    0.
                                                      K -.1171E+06  .694[illegible]+07 -.2202E+08 0.       .1[illegible]4E+08 0.   0.
                                                      M .[illegible]140E+06 -.222[illegible]+07 -.4407E+07 0.    .5112E+05 0.     .[illegible]388E+07
                                                      N -.9[illegible]E+04  .426[illegible]+08 -.413[illegible]+08 0.  0.       0.       0.

TIME   U     V     W     PHI   THETA  BETA      FIN           RUDDER        HULL          AERO    BUOYANCY      RATE    PROPULSION
93.0   8.18  -.42  -.02  -.05  0.00   .05     X -.2215E+04  -.565[illegible]E+06 -.5482E+06 0.       0.            0.       .1165E+07
                                                      Y 0.          -.1474E+07    .2443E+07 0.         0.            0.       0.
                                                      Z .1432E+05  0.             .2725E+06 0.       -.2444E+06 0.     0.
                                                      K -.1660E+05  .694[illegible]+07 -.221[illegible]+08 0.   .1215E+08 0.   0.
                                                      M .4128E+06  -.2227E+07   -.4407E+07 0.       .5[illegible]05E+05 0.   .9392E+07
                                                      N -.1088E+04  .425[illegible]+08 -.4199E+08 0.  0.            0.       0.

TIME   U     V     W     PHI   THETA  BETA      FIN           RUDDER        HULL          AERO    BUOYANCY      RATE    PROPULSION
96.0   8.18  -.41  -.03  -.06  0.00   .05     X -.2848E+04  -.5652E+06  -.5489E+06 0.       0.            0.       .1165E+07
                                                      Y 0.          -.1473E+07    .2401E+07 0.         0.            0.       0.
                                                      Z .1723E+05  0.             .2726E+06 0.       -.2351E+06 0.     0.
                                                      K .9[illegible]26E+05 .6941E+07 -.2197E+08 0.     .1496E+08 0.     0.
                                                      M .4[illegible]59E+06 -.2228E+07 -.4406E+07 0.    .5104E+05 0.     .9392E+07
                                                      N .6918E+04  .425[illegible]+08 -.4377E+08 0.  0.            0.       0.

TIME   U     V     W     PHI   THETA  BETA      FIN           RUDDER        HULL          AERO    BUOYANCY      RATE    PROPULSION
99.0   8.18  -.43  -.03  -.07  0.00   .05     X -.3037E+04  -.5652E+06  -.5479E+06 0.       0.            0.       .1165E+07
                                                      Y 0.          -.1473E+07    .2403E+07 0.         0.            0.       0.
                                                      Z .2021E+05  0.             .2727E+06 0.       -.2289E+06 0.     0.
                                                      K -.1369E+05  .6941E+07   -.2185E+08 0.       .1759E+08 0.     0.
                                                      M .5817E+06  -.2228E+07   -.4406E+07 0.       .4969E+05 0.     .9389E+07
                                                      N -.1393E+04  .4257E+08   -.4292E+08 0.       0.            0.       0.

TIME   U     V     W     PHI   THETA  BETA      FIN           RUDDER        HULL          AERO    BUOYANCY      RATE    PROPULSION
102.0  8.18  -.44  -.02  -.06  0.00   .05     X -.2788E+04  -.5654E+06  -.5481E+06 0.       0.            0.       .1165E+07
                                                      Y 0.          -.1474E+07    .2440E+07 0.         0.            0.       0.
                                                      Z .1791E+05  0.             .2726E+06 0.       -.2369E+06 0.     0.
                                                      K -.9316E+05  .6944E+07   -.2205E+08 0.       .1473E+08 0.     0.
                                                      M .4923E+06  -.2228E+07   -.4407E+07 0.       .5143E+05 0.     .9390E+07
                                                      N -.7581E+04  .425[illegible]+08 -.4145E+08 0.  0.            0.       0.

TIME   U     V     W     PHI   THETA  BETA      FIN           RUDDER        HULL          AERO    BUOYANCY      RATE    PROPULSION
105.0  8.18  -.42  -.02  -.05  0.00   .05     X -.2303E+04  -.5654E+06  -.5481E+06 0.       0.            0.       .1165E+07
                                                      Y 0.          -.1474E+07    .2433E+07 0.         0.            0.       0.
                                                      Z .1484E+05  0.             .2725E+06 0.       -.2419E+06 0.     0.
                                                      K .1454E+05  .6943E+07    -.2213E+08 0.       .1278E+08 0.     0.
                                                      M .4707E+06  -.2227E+07   -.4407E+07 0.       .5252E+05 0.     .9393E+07
                                                      N .3936E+03  .4257E+08    -.4241E+08 0.       0.            0.       0.

TIME   U     V     W     PHI   THETA  BETA      FIN           RUDDER        HULL          AERO    BUOYANCY      RATE    PROPULSION
108.0  8.18  -.41  -.03  -.06  0.00   .05     X -.2866E+04  -.5652E+06  -.5490E+06 0.       0.            0.       .1165E+07
                                                      Y 0.          -.1473E+07    .2402E+07 0.         0.            0.       0.
                                                      Z .1904E+05  0.             .2726E+06 0.       -.2342E+06 0.     0.
                                                      K .7040E+05  .6941E+07    -.2194E+08 0.       .1560E+08 0.     0.
                                                      M .5297E+06  -.222[illegible]+07 -.4406E+07 0.    .509[illegible]+05 0.   .9392E+07
                                                      N .4[illegible]0E+04 .425[illegible]+08 -.435[illegible]+08 0.  0.       0.       0.

TIME   U     V     W     PHI   THETA  BETA      FIN           RUDDER        HULL          AERO    BUOYANCY      RATE    PROPULSION
111.0  8.18  -.43  -.03  -.07  0.00   .05     X -.2[illegible]7E+04 -.5652E+06 -.5479E+06 0.      0.            0.       .1165E+07
                                                      Y 0.          -.1473E+07    .2412E+07 0.         0.            0.       0.
                                                      Z .1[illegible]1E+05 0.           .272[illegible]+06 0.   -.229[illegible]+06 0.   0.
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                                           K  -.2[illegible]     .[illegible]         -.[illegible]     0.            .1[illegible]+08  0.          0.
                                           M   .[illegible]+06  -.2[illegible]F+07  -.44[illegible]+07  0.            .4[illegible]F+05  0.          .5390E+07
                                           N  -.24[illegible]+04   .425[illegible]    -.42[illegible]+08  0.            0.         0.          0.

 TIME    U      V      W     PHI   THETA   BETA        FIN       RUDDER      HULL       AERO       BUOYANCY      RATE      PROPULSION
114.0   8.18  -.43   -.0[illegible]  -.0[illegible]  0.00    .0[illegible]  X  -.[illegible]+04  -.56[illegible]+0[illegible]  -.[illegible]+06  0.            0.         0.          .1165E+07
                                           Y  0.                -.1474F+07   .2430[illegible]+07  0.            0.         0.          0.
                                           Z   .1[illegible]+05  0.                 .272[illegible]+06  0.           -.23[illegible]+06  0.          0.
                                           K  -.[illegible]+05   .[illegible]F+07  -.2207F+08  0.            .1425E+08  0.          0.
                                           M   .477[illegible]+06  -.22[illegible]F+07  -.4407F+07  0.            .[illegible]+05  0.          .5391F+07
                                           N  -.5[illegible]+04   .425[illegible]    -.4166E+08  0.            0.         0.          0.

 TIME    U      V      W     PHI   THETA   BETA        FIN       RUDDER      HULL       AERO       BUOYANCY      RATE      PROPULSION
117.0   8.18  -.42   -.02   -.05   0.00    .0[illegible]  X  -.2405F+04  -.565[illegible]+0[illegible]  -.[illegible]91E+06  0.            0.         0.          .1165F+07
                                           Y  0.                -.1474F+07   .2426F+07  0.            0.         0.          0.
                                           Z   .1[illegible]4E+05  0.                 .2725E+06  0.           -.2400F+06  0.          0.
                                           K   .2056F+05   .[illegible]+07  -.2209[illegible]+08  0.            .1343E+08  0.          0.
                                           M   .4[illegible]F+06  -.2227E+07  -.4407F+07  0.            .5209F+05  0.          .5393F+07
                                           N   .1151F+04   .425[illegible]+0[illegible]  -.4269F+08  0.            0.         0.          0.

TIME=    27.000      HALVE INTERVAL.  EQUATION   4 HAS ERROR=    .16659375F+00        STEP SIZE NOW =    .15000000F+01
 Y2
 .88496F+01  -.35921F+00  -.37050F-01   .11260F-02  -.39942F-02   .37166F-01  -.10726F+00  0.            .27820F+00   .29662E+03
 .82156E+01   .13621F+00   .29725E+03
 Y1
 .88092E+01  -.35581E+00  -.39739F-01   .61431E-03  -.38477F-02   .37178E-01  -.10370F+00  0.            .27862F+00   .29663E+03
 .81899F+01   .13527F+00   .2972[illegible]F+03
      0.003.00000000
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      9.003.00000000
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    111.001.50000000
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